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EDITED BY

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(WITH EXPLANATORY TEXT).

Compiled from the latest sources by FELIX OSWALD, D.Sc., F.G.S.

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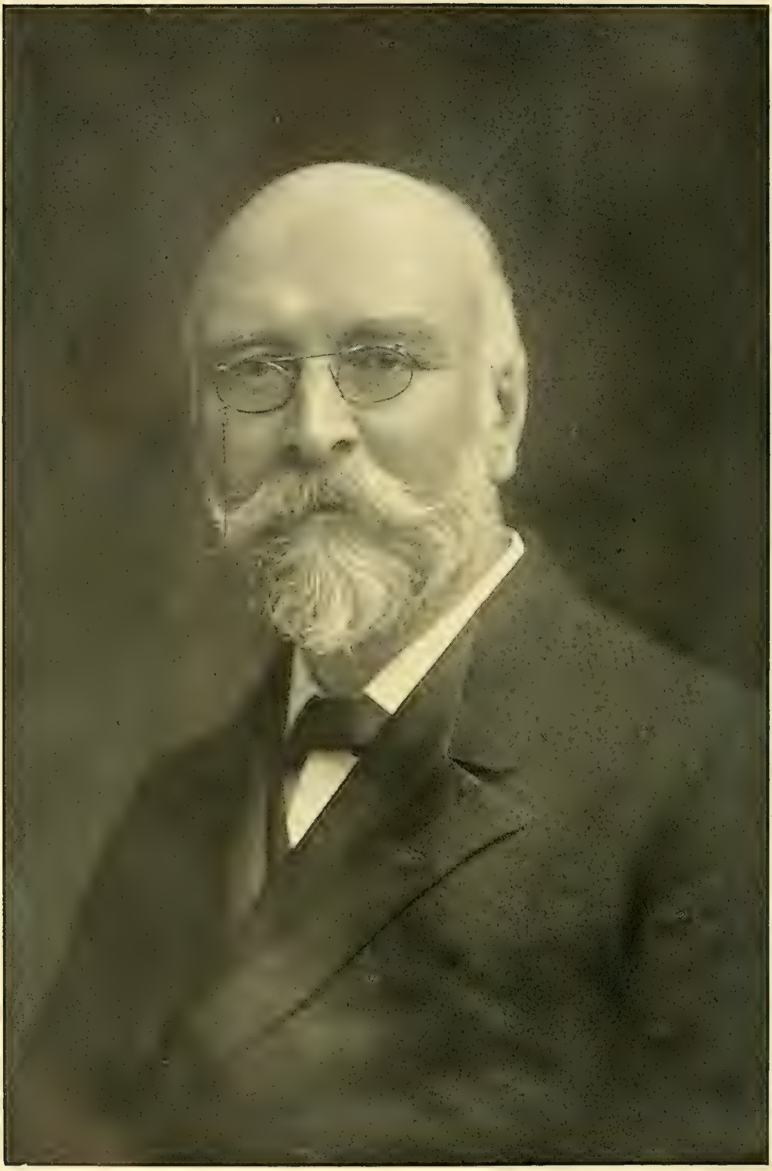

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A. Smith Woodward.

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THE

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NEW SERIES. DECADE VI. VOL. II.

No. I.—JANUARY, 1915.

MAR 1 [illegible]
National Museum

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Arthur Smith Woodward, LL.D. (St. Andrews, Glasgow), F.R.S., F.L.S., F.G.S., F.Z.S., F.R.G.S., Keeper of the Department of Geology, British Museum (Natural History).

(WITH A PORTRAIT, PLATE I.)

In presenting a portrait and offering to the readers of the Geological Magazine a brief memoir of Dr. Arthur Smith Woodward, my namesake and successor in the Geological Department of the British Museum (Natural History), I feel that no apology is needed, inasmuch as every lover of our science will be glad to possess a record of one of its leading men whom he may have met already, and known generally, but may wish for a more personal acquaintance, which this sketch is intended to furnish.

Henry Woodward.

Arthur Smith Woodward was born at Macclesfield on May 23, 1864, and began in his early school-days to take a keen interest in natural science. His special bent towards geology was fostered by the teaching of the Rev. S. G. Waters at the Macclesfield Grammar School and by the facilities the district afforded for practical work in the field. His inclination towards the study of fossils was also increased by an annual holiday at Llandudno, within reach of the Carboniferous Limestone of the Great Orme's Head. In 1880 he proceeded to the Owens College, Victoria University of Manchester, where he came under the influence of Professor Boyd Dawkins, and in 1882 he obtained by competitive examination a Second Class Assistantship in the Geological Department of the British Museum, under the Keepership of Dr. Henry Woodward.

Since 1882 Dr. Smith Woodward's scientific activities have centred entirely in the Geological Department of the British Museum, of which he became Assistant-keeper (in succession to Mr. Robert Etheridge, F.R.S.) in 1892 and Keeper (in succession to Dr. Henry Woodward, F.R.S.) in 1901. He began his career in immediate association with Mr. William Davies, who was Assistant in special charge of the fossil Vertebrata, and during the whole of his period of service he has devoted himself particularly to the study of Vertebrate Palæontology.

In 1883 the Swiney Lecturer at the British Museum was Dr. R. H. Traquair, F.R.S., who selected Fossil Fishes as his subject, and expounded the general principles to which his own exhaustive researches had led him. Arthur Smith Woodward took elaborate notes of these lectures, and made use of them while assisting Mr. William Davies in incorporating the great Egerton and Enniskillen Collections of Fossil Fishes, which had previously been acquired by the British Museum. His curatorial work showed him that the collection of Fossil Fishes in the Museum then provided ample material for placing the study of these fossils on an entirely new basis in the light of recent discoveries. He thus began to devote his leisure to some preliminary researches, which led the Trustees of the British Museum, on the recommendation of the Keeper of Geology, to entrust to him the preparation of an exhaustive Catalogue of Fossil Fishes, which absorbed most of his energies between 1887 and 1901, and was completed in four large volumes. The work of E. D. Cope and R. H. Traquair especially laid the foundation for the new point of view from which the subject was regarded, and a large proportion of the changes in classification and interpretation of the various groups of extinct fishes proposed in the Catalogue have now been generally adopted. The first volume was noteworthy for the earliest adequate recognition of the primitive character of the Palæozoic sharks, and for the detailed description of many Mesozoic sharks, such as *Hybodus* and *Acrodus*, which had previously been known only in a vague manner. The second volume added much to our knowledge of the problematical Acanthodians and Ostracoderms, and other Palæozoic groups of so-called 'ganoids', emphasizing the importance of fin-structure in classification already recognized by Cope and Traquair. The third volume provided the first series of detailed osteological descriptions of many groups of Mesozoic 'ganoids', while the fourth volume was devoted to a critical synopsis of our knowledge of the bony fishes. During the progress of this work and subsequently Dr. Woodward published upwards of 200 small descriptive papers on various fossil fishes, besides three memoirs on the Permo-Carboniferous, Triassic, and Jurassic Fishes of New South Wales (for the Geological Survey of that country), a memoir on the Carboniferous Fishes of Victoria, Australia (for the Melbourne Museum), a Monograph of the English Chalk Fishes (for the Palæontographical Society), and a memoir on the Fossil Fishes of the Whitby Lias (for the Yorkshire Geological Society), all profusely illustrated with lithographic plates. He was also a pioneer in the description of the fossil fishes of South Africa, Brazil, Greenland, and Spitzbergen.

During the preparation of the Catalogue of Fossil Fishes, Dr. Woodward spent most of his vacations in foreign countries to examine the collections in other Museums, and became personally acquainted with those who were pursuing researches on fossil fishes abroad. He has also made similar use of his vacations in connexion with other palæontological work since the Catalogue was completed. He has thus been led to take a gradually widening interest in many departments of vertebrate palæontology, and so long ago as 1898 he prepared an elementary treatise, *Outlines of Vertebrate Palæontology for Students of Zoology*, which was published by the Cambridge University Press. Four journeys to North America in 1890, 1900, 1904, and 1909, have enabled him to follow closely the wonderful progress made during the last twenty-five years on that continent, while two journeys to South America, in 1896 and 1907, have furnished material for many original papers. During one of his three visits to Greece, in 1901, he was officially commissioned by the Trustees of the British Museum to supervise diggings at Pikermi for fossil mammals, of which he returned with a large collection. During his vacations in Spain, in 1902 and 1905, he obtained many similar fossil mammals from Concud, in Aragon, while in 1908 and 1910, in the same country, he collected rare Jurassic fishes in the Province of Lérida, and visited the well-known painted caves near Santander.

Among Dr. Woodward's papers, other than those on fossil fishes, which resulted from these various journeys, may be specially mentioned those on the fossil reptiles and certain mammalian remains from South America, which he published with the co-operation of Dr. Francisco P. Moreno, founder of the Museum of La Plata. He described and interpreted a new Mesozoic crocodile, *Notosuchus*, from the Cretaceous of Neuquen, Patagonia, related to the crocodiles from the English Purbeck Beds; also one of the most primitive known snakes, *Dinilysia*, from the same formation. In the same district were found the remarkable skull and other remains of *Miolania argentina*, which he compared in detail with the similar extinct horned tortoises from Queensland and Lord Howe's Island, and discussed in connexion with the theory of a former antarctic continent, connecting Australia and South America. He concluded that the discovery of *Miolania* did not necessarily support the theory because it was related to a practically cosmopolitan Jurassic group of Chelonia. Among later fossils he prepared for the Zoological Society in 1899 and 1900 the first detailed account of the dried skin and associated bones of the Ground Sloth, *Grypotherium listai*, which excited so much interest and speculation when they were found in the Eberhardt cave at Last Hope Inlet, Southern Chile. His interpretation of the original piece of skin proved to be correct when the skull and other bones of the animal were subsequently discovered.

Dr. Woodward's other papers on the higher vertebrates include several accounts of British fossils. In 1905 he described Mr. Alfred Leeds' discovery of the limbs and tail of *Cetiosaurus leedsi* from the Oxford Clay of Peterborough, and showed that this Dinosaur resembled the American *Diplodocus* in having a long lash at the end of its tail. In 1910, when describing Mr. F. L. Bradley's discovery of a skull of *Megalosaurus* in the Great Oolite of Minchinhampton, he pointed out that this Dinosaur also agreed with its American representative, *Ceratosaurus*, in the possession of a horn on the nose. In 1907 he made known Mr. William Taylor's remarkable discovery of a dwarf leaping Dinosaur, *Scleromochlus taylori*, in the Triassic Sandstone of Elgin, and in the same year he published the first exhaustive description of the Triassic Rhynchocephalian, *Rhynchosaurus*, in the Report of the British Association. Among mammals, his first important paper was on the discovery of the Saiga Antelope in the Thames gravels at Twickenham in 1890. In 1891 and 1912 he also had the satisfaction of recording the first discoveries of mammalian teeth in the Wealden of Sussex by Mr. Charles Dawson and Father P. Teilhard. During the past three years he has co-operated again with Mr. Dawson in exploring the remarkable gravel deposit at Piltdown, Sussex, whence was obtained the lowest type of human skull and mandible hitherto known. His interpretation of this specimen and his reference of it to a new genus, *Eoanthropus,* were at first much criticized by certain human anatomists; but the actual discovery of the large ape-like canine tooth which he had predicted, and a renewed study of the cranial bones, have shown that his original conclusions were in the main justifiable.

Each volume of the Catalogue of Fossil Fishes was prefaced by an Introduction summarizing the results and suggesting some theoretical deductions, and during all his studies Dr. Woodward has attempted to consider their bearing on current philosophy. In 1904 he expounded his general views in an address delivered to the International Congress of Science and Arts at the St. Louis Exposition, and in 1906 he treated fossil fishes from the same standpoint in his Presidential Address to the Geologists' Association of London. In 1909 he returned to the same subject at Winnipeg, in his Presidential Address to Section C at the British Association Meeting, and in 1913 he treated it again in a popular manner in an Evening Lecture to the British Association at Birmingham. He follows the American school, founded by Cope, Hyatt, and Beecher, and is specially insistent on the truth of the doctrine of orthogenesis.

While pursuing original researches with continual energy, Dr. Woodward has not neglected the curatorial aspect of his duties, and his extensive acquaintance with fellow-workers both at home and abroad has enabled him to maintain the Geological Department of the British Museum during his Keepership in the forefront of progress. Fossils of nearly all groups from Africa, fossil lemurs from Madagascar, mammals from Asia, vertebrates of all kinds from South America and North America, mammals from the Mediterranean Islands, and Dinosaurs from Transsylvania, besides numerous important collections from the British Isles, have not only added immensely to knowledge and to the facility for making comparative studies, but have also improved the exhibited collection by substituting many complete specimens for fragments. Among the latter may be specially mentioned the dwarf *Hippopotamus* from Crete, the restored model of *Arsinoitherium* from Egypt, the skeleton of *Halitherium* from Germany, *Diprotodon* from Australia, the wonderful skeletons of *Ophthalmosaurus*, *Steneosaurus*, and *Cetiosaurus* from the Oxford Clay of Peterborough, the great fish *Portheus molossus* from the Chalk of Kansas, and the giant merostome *Pterygotus anglicus* from the Old Red Sandstone of Forfarshire. Besides these must be remembered the extensive collections of smaller fossils which have been added to the study-cabinets.

Dr. Woodward has not confined his administrative work to the British Museum, but has also taken some share in many other scientific affairs. For some years he has been a member of the Advisory

Committee on the Geological Survey appointed by the President of the Board of Education, and in 1914 he occupied the Chair. For many years he has been a member of the Boards of Studies in Zoology and Geology in the University of London. Since 1901 he has been Secretary of the Palæontographical Society and Editor of its Monographs. He has served on the Councils of the Royal Society, the British Association, the Linnean, Geological, and Zoological Societies, and the Geologists' Association. He was Vice-President of the Linnean and Zoological Societies for several years, occupied the Presidency of the Geologists' Association in 1904-6, was Secretary of the Geological Society for six years, and became President of the Geological Society in 1914. In 1889 he was awarded the Wollaston Donation Fund, and in 1896 the Lyell Medal of the Geological Society. In 1900 he received the Honorary Degree of LL.D. from the University of Glasgow, and in 1912 the same Degree from the University of St. Andrews. In 1914 he was awarded the Clarke Medal by the Royal Society of New South Wales. He has also been honoured abroad by election as Foreign Member of the Société Belge de Géologie, and as Corresponding Member of the New York Academy of Sciences and the Boston Society of Natural History.

After thirty-two years' strenuous work in the Museum Dr. Arthur Smith Woodward still retains the same untiring energy which has impelled him since his earliest years to study hard and to travel. Few scientific men can lay claim to so large a share of solid work in his own special department or to have done more individually to advance geology and palæontology, the sciences to which he has devoted his life.

His principal separate publications are :—

1899–1901. *Catalogue of the Fossil Fishes in the British Museum (Natural History)*, pts. i–iv.

1890. [With Charles Davies Sherborn.] *A Catalogue of British Fossil Vertebrata.*

1898. *Outlines of Vertebrate Palæontology for Students of Zoology.*

1902–12. *The Fossil Fishes of the English Chalk.* Monograph of the Palæontographical Society.

He has also contributed 230 separate papers to scientific journals and proceedings of various societies at home and abroad, including upwards of fifty papers to the Geological Magazine.

II.—Studies in Edrioasteroidea. VI. *Pyrgocystis* n.g.[1]

By F. A. Bather, M.A., D.Sc., F.R.S.

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(PLATES II, III.)

MATERIALS for the study of this very distinctive genus have been accumulating for many years, and at last afford a firm basis for certain definite conclusions. Some important matters remain obscure, and the comparison of the Swedish material has been hindered by the dangerous state of the North Sea, but further delay

[1] Study V appeared in the Geological Magazine for May, 1914.

in publication does not seem advisable. Various reasons make it convenient to deal with the species in the order of their geological age, beginning with the oldest, which is the most complete and is taken as the type-species of the genus. The new species are—

Pyrgocystis sardesoni, Lower Ordovician, Minnesota (genotype).
Pyrgocystis grayae, Upper Ordovician, Girvan.
Pyrgocystis ansticei, Middle Silurian, Shropshire.

To this genus are also referred some fossils from the Middle Silurian of Gotland which C. W. S. Aurivillius in 1892 regarded as representing seven species of the Cirripede genus *Scalpellum*. Though possibly to be reduced to only two species, they all appear to be distinct from the new species mentioned above.

The essential characters of the genus are displayed most clearly by the genotype *P. sardesoni*, to the description of which we now proceed.

A. *Pyrgocystis sardesoni* n.sp. (Plate II, Figs. 1–6.)

In March, 1901, Dr. F. W. Sardeson, of the University of Minnesota, himself a student of Palæozoic Pelmatozoa, was so generous as to send to me for study and description the rare and interesting fossils which give rise to this new genus, although he had originally intended to write on them himself. Not only this, but he has permitted me to retain the best specimen, returning him the others. Preliminary studies were made and drawings were prepared without undue delay, but various causes have up till now prevented the publication of the paper. This may seem a poor return for Dr. Sardeson's confidence, but the work at any rate has not suffered by keeping. It only remains for me to express my profound appreciation of his extraordinary kindness.

Horizon and Locality.—"The three specimens," says Dr. Sardeson, "compose all of the set, collected from the Ordovician Galena series, Stictopora bed; at St. Paul, Minnesota. The exact spot is a quarry on the west bluff of the Mississippi river, opposite the outlet at the east end of 'Pickerel Lake', as given on maps of St. Paul city."

The position of the Stictopora or, more correctly, Stictoporella bed in the Minnesota section is well known, but opinion as to the correlation with other regions has undergone much change The bed lies above the Platteville limestone and at the base of a series of shales successively termed Trenton, Black River, and Decorah, and now considered by E. O. Ulrich to represent the upper part of the Black River formation (see his "Revision of the Palæozoic Systems", Bull. Geol. Soc. Amer., vol. xxii, pl. 27; August, 1911). The Stictoporella bed comprises soft green shales and thin-bedded limestones, and is particularly rich in Polyzoa. According to R. S. Bassler (December, 1911, Bull. U.S. Nat. Mus., lxxvii, p. 38), the Decorah Shales correspond generally to the beds of Baltic Russia from the Wassalem beds (D 3) down to the Glauconite sandstone. But since the Kimmswick Limestone of Missouri (which corresponds to the top of the Decorah shales or even overlies them) contains a species of *Echinosphæra* said to be scarcely, if at all, distinguishable from

E. aurantium, it seems probable that the shales themselves correspond rather to the Orthoceras and Glauconite limestones which lie below the Echinosphæra limestone of N.W. Europe.

Material.—The three specimens may be denoted A, B, and C. A is taken as Holotype, and, having been so generously presented to the British Museum by Dr. Sardeson, is there registered as E 16,232. It was collected a few months before the other specimens, and probably came from a more exposed position, since it is partly weathered reddish-brown, whereas they are more grey. It is also rather better preserved, both as a whole and in detail, and the matrix has been more easily removed. B and C remain the property of Dr. Sardeson.

General Description.—A circular oral surface of general Edrioasteroid type, with (presumably five) straight broad subvective grooves, surmounts a cylindrical turret built up of scale-like plates imbricating from below upwards (i.e. adorally). The diameter of the turret is about two-thirds of its height. The scales bore spinules on their free borders; the oral face is obscured by longer movable spines.

Detailed Description.—The Oral Face is preserved well enough for description only in A, and here it is the perfectness of preservation that militates against description, since the greater part of the surface is covered by spines (Pl. II, Figs. 1, 2).

The diameter of the oral face is about 8 mm. Portions of four subvective grooves are visible; these are so situated that they appear to be on four adjacent rays out of a total of five; but which four they may be it is not easy to say. Two of the interradii, which are less covered with spines than the rest, are clearly neither of them the anal (posterior) interradius. Of the three remaining interradii, it is noteworthy that in one several of the spines, which seem to be a little longer, are directed towards a point at the margin of the oral face; and this suggests that the spines in question surround the anal opening. Taking this as a working hypothesis, for the present irrefutable, we find that the completely unexposed ray is the right posterior.

The Subvective Groove of the supposed anterior ray is seen to attain a width of 1·65 mm., and to be composed of a double series of plates, apparently alternating on the median line, and passing from that line outwards in a distal direction, so as to form an angle of about 140°. At the rounded distal extremity the angle becomes more acute, as the plates assume the usual fan-like arrangement. There are about five of these plates within a distance of 1 mm. An imaginary section across the whole structure shows the median line depressed, and the sides rising in a gentle convex curve, and then sinking again towards the outer edge of the ray or groove, so that this is clearly differentiated from the surrounding plates.

Of the right anterior groove, only a small portion is exposed, and this shows about five plates of one side all fenced round by spines. Each of these plates bears two tubercles, one on each brow of the convex curve, well raised above its general surface, and each depressed in its centre. It is natural to suppose that to each of these 'perforate' tubercles was articulated a spine, and this interpretation is confirmed by the position of some of the neighbouring spines. Such tubercles were no doubt present on all the similar plates of this and of the other grooves, but of those other grooves it is only the left posterior which retains at all obvious traces of them; on the exposed portions of the remaining grooves they seem to have been less protected by preserved spines, and so to have been worn away.

The homologies of the alternating plates of the grooves are not quite certain. Presumably they must be either floor-plates or cover-plates. Since it is plain that they bore spines, they must have been, at least in part, on the exterior; and one would naturally infer that they were cover-plates. But they seem thicker and more curved and rounded than the cover-plates in Edrioasteridæ; and they might conceivably be floor-plates of which the elevated portions were exposed, leaving only the edges, especially near the median line, to be protected by small cover-plates now removed or unrecognizable. *Lebetodiscus* (Study III, December, 1908) presents such a structure, but in *L. dicksoni* the pores between the floor-plates are clear, whereas there is no trace of pores in *Pyrgocystis sardesoni*.

The Interradial Plates of the oral face are best exposed in the left anterior interradius, and to a less extent in the right anterior interradius. They merge into the imbricating plates of the turret, and the appearance is as though the turret-plates gradually became vertical and then inclined towards the oral centre. At the same time they become slightly thicker and much narrower, so that their relative thickness is considerably increased.

In part of the right anterior interradius and in the three other interradii these plates are obscured by Spines. Since these spines are of the same character as those on the grooves, it may be inferred that they were borne by similar tubercles. In the exposed interradii, however, such tubercles cannot be distinguished among the numerous irregularities of the surface. In the left posterior interradius some tubercles seem to be exposed, but it is difficult to distinguish between them and the ends of prostrate spines.

In the posterior interradius, as already stated, several spines, perhaps rather longer than most, are all directed in one way, and some of these converge to a point on the margin, to the right of the posterior interradius. A similar disposition of spines to protect the anal opening is common in spiniferous echinoderms.

The spines attained, in some cases at any rate, a length of not less than 1·3 mm. and a diameter of ·12 mm., tapering gently near the distal end. They show no sign of longitudinal striation, but are often irregularly blotched with black, which represents carbonized stroma and indicates a relatively wide-meshed stereom.

The Turret on which the oral face is supported has in specimen A (Pl. II, Fig. 4) a height of 13·2 mm., and it is uncertain whether the actual base is preserved; the cross-section is somewhat elliptical, with diameters of 10·8 mm. and 8·8 mm. In specimen B (Pl. II, Fig. 6), which seems to be still attached to a piece of rock, the height is 10 mm., and the diameters about 11 and 10 mm.; but here some of the adoral end may be missing. Specimen C (Pl. II, Fig. 3) has a height of about 11·5 mm., with diameters 10·8 and 8·2 mm.; and here both ends may be incomplete. If allowance be made for imperfections and crushing, we may legitimately imagine a normal height of about 14 mm., and a diameter of 9·8 mm., or say two-thirds the height. The diameter seems to have been the same all the way up, and there is no indication that the turret was curved.

This turret is built up of a large number of separate thin plates, imbricating in such a way that their outer or free ends are directed upwards, i.e. towards the adoral face (Pl. II, Fig. 4). At the base of the turret these plates lie almost horizontally, but the inward dip gradually increases with each successive layer. The thickness of the turret wall is therefore at the base equal to the diameter of a plate; in A and C this amounts to at least 1·3 mm., leaving a lumen of about 7 mm. diameter (Pl. II, Fig. 3). Higher up the thickness does not decrease, but is formed rather by the combined thicknesses of the imbricating plates. The disc or body of the animal seems thus supported by the turret as a bird on its nest (Pl. II, Fig. 6). The arrangement of the imbricating plates is not very regular, but those of one tier tend to alternate with those of the tier below. In A the number of plates exposed along a single vertical line from top to bottom is about twenty-four; this means that the number of tiers is about forty-eight. About ten plates (twenty tiers) occur within 5 mm., but the plates are more widely separate above than they are below. Near the base four plates may be exposed along a vertical line of 1 mm., but this is in part due to the fact that the alternation is less regular, so that in these regions the number of tiers within the same distance would be only five or six, not eight. In the absence of a vertical section it is not possible to estimate precisely the proportion of each plate exposed, i.e. the extent of overlap; but the actual depth of the exposed portion in the upper part of the turret is about ·5 mm. It seems safe to say that not more than one-third of the plate is ever exposed.

No one of the turret plates can be entirely isolated, but in general outline those near the base may be compared to a salad-plate, with a slight concave curve next the lumen of the turret, and a stronger convex curve on the outside (Pl. II, Fig. 3). The convex curve is more pronounced in plates from the upper part of the turret. In specimen A a plate at the base has a width of about 3·75 mm. In other plates the width seems to have exceeded this, and to have about thrice the diameter. Probably the plates below are wider than those above.

Specimens A and C are laterally compressed, so that the cross-section of the turret may be said to have flat sides and rounded ends. Whether it bear any causal relation to this compression or no, it is the case that the tiers of turret-plates sink towards the base on the sides and rise towards the ends. This is visible at the very base in A.

In specimen C, which is generally of a yellowish-grey colour, the turret-plates are spotted with black in their stereom, and the spots are chiefly conspicuous on the free borders, where they seem rather regularly spaced. The meaning of these spots is suggested by A, for there, on the free borders of the turret-plates, are what appear to be short spines, at fairly regular intervals of about ·2 mm., and each a little more than ·1 mm. long (Pl. II, Fig. 5). These spinules were, one supposes, attached to the turret-plates by strands of stroma, and it is the carbonized remains of the latter that form the black spots.

Diagnoses of the genus and of the species will follow the descriptions of the other species.

EXPLANATION OF PLATE II.

Pyrgocystis sardesoni.

FIG. 1. Specimen A. Oral face. The supposed anterior ray is uppermost; the bunch of spines supposed to be over the anal opening is near the lower margin, slightly to the right; above this on the right is exposed a part of the right anterior ray with tubercles. × 7·5 diam.

,, 2. Specimen A. Oral face. This photograph was taken before the specimen had been prepared quite so much as shown in Fig. 1. × 3 diam.

,, 3. Specimen C. Lower or distal end of turret, showing the large lumen. On the right the wall is bent inwards a little. × 3 diam.

,, 4. Specimen A. The turret from the supposed posterior side. × 3 diam.

,, 5. Specimen A. Part of the turret wall seen in Fig. 4, further enlarged to show the spinules. × 11 diam.

,, 6. Specimen B. The turret seen partly from above, showing how the centre is filled with plates. Portions of the shelly matrix still adhere to the sides of the turret, which is attached to a small fragment of rock. × 3 diam.

Figures 2, 4, and 5 are from photographs taken and worked up by Mr. Walter Moran. Figures 1, 3, and 6 are by the Author.

B. PYRGOCYSTIS GRAYAE n.sp. (Pl. III, Figs. 1, 2.)[1]

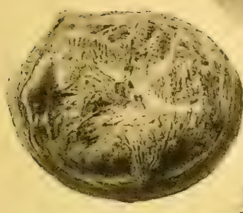
Material, Locality, and Horizon.—Among the echinoderms collected by Mrs. Robert Gray in the Starfish Bed of Thraive Glen, Girvan, is one, numbered by me K 8, which in general structure closely resembles Dr. Sardeson's fossil. The Starfish Bed lies near the summit of the Ordovician, as proved by the work of many geologists and palæontologists, whose remarks were summarized in my memoir on Caradocian Cystidea from Girvan (1913, Trans. R. Soc. Edin., vol. xlix, No. 6, §§ 6–8), where also the relationships of the Cystid fauna to those of other countries were discussed (§§ 559–568). Like all the fossils from the Starfish Bed described in that memoir, the present one is an imprint, and only one side is preserved.

General Description.—The differences between this, for the present, unique Girvan fossil and those from St. Paul lie mainly in the greater elongation and tapering of the turret and the elevation of the oral face into a high dome.

Detailed Description.—The oral face is mounted on a kind of Cup distinct from the stem or turret. This cup is formed apparently of thin imbricating plates, serially homologous with those of the turret, but higher and more closely united. At the top they are almost square-cut. In radial position they seem to bear no definite relation to either the rays of the oral face or the vertical rows of plates in the turret. Although these plates overlap at the sides, they all appear to

[1] Plate III, containing the figures of *Pyrgocystis grayae*, will be given with the second half of the paper in the February Number.

1



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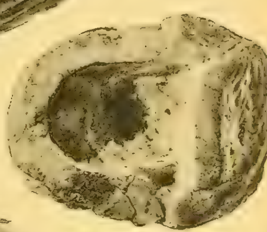

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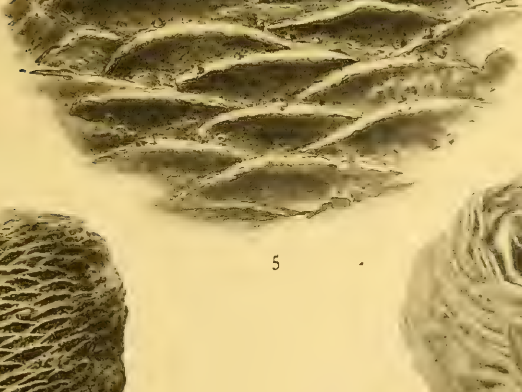

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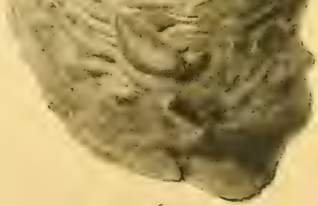

6

be of the same height and to reach approximately the same level. This height is about 1·3 mm. as measured from the top of the turret. The diameter of the cup at its upper margin is 4·7 mm., and below is about 3·8 mm.

The dome of the Oral Face reaches at its oral pole a height of 3·2 mm. above the cup, i.e. 4·5 mm. above the turret.

A single Subvective Groove faces the observer, and others are less clearly seen, one at each side. The groove attains a width of 1·7 mm., and is filled with alternating plates, which, as in *P. sardesoni*, may be either cover-plates or floor-plates. These plates are directed from the perradius outwards in a distal direction; the angle at which they meet is not easy to measure, but may be estimated at about 133°. The distal end of the groove is pressed against the plates of the cup, so that the arrangement of the terminal groove-plates cannot be made out. There are about three of these plates within a distance of 1 mm. A section across the groove-structures would show a broad convex curve sinking rather rapidly at each end towards the interradial area. The sutures between the groove-plates are depressed, especially along the median line of the groove, and appear rather irregular, as if they were either slightly crenelate and interlocking, or marked with alternating notches. There seems to be slight adoral imbrication of these plates.

Towards the oral pole the groove narrows considerably, and the curve of the cross-section is more markedly convex, almost angular. At the oral pole the groove-plates appear to meet those of the other rays, and there is no depression. That affords an argument for the plates being cover-plates.

The Interradial Plates of the oral face are hard to interpret. There seems to have been a single large plate within, and as it were continuing, the large overlapping plates of the cup. Then between this and the adoral groove-plates seems to be a single small plate.

The precise relation of these two interradial plates to the groove-plates is not easy to make out. There are appearances which remind one of the depressed sutures which in *Steganoblastus* continue the line of the sutures between the cover-plates. It might be inferred from this that the groove-plates, whether cover-plates or floor-plates, were in places separated from the larger interradial plates by small plates continuing the same line.

The surface of all the plates of the oral face is slightly rough, but it is not possible to say whether or no they bore spines.

The Turret is distinctly separated from the cup, at least in this unique specimen, owing to the fact that the cup-plates are more vertical, or in other words more parallel to the long axis of the animal, than are the uppermost turret-plates, and this divergence of angle results in a groove where they meet. It is, no doubt, conceivable that in other individuals, or even in this individual under other conditions of muscle-tone in life or of preservation in death, the uppermost turret-plates might be applied closely to the plates of the cup; but the distinction between cup and turret would be none the less decided, by reason of the less height of the turret-plates, or at any rate of their exposed portion. There is no reason to suppose that the adoral region has been subjected to any such crushing or pulling as might have dragged it away from the rest. The turret then, for purposes of this description, is limited to the smaller plates, although in origin they must be of the same nature as the cup-plates.

The turret is clearly preserved for a distance of 13 mm. below the cup; beyond that distance, for 7 mm., the plates are much disturbed, but it is quite probable that the total height of the turret was 20 mm.

The diameter of the turret at its upper (proximal) end is 4·3 mm. Thence it tapers gradually, till at 13 mm. from the cup the diameter is 3·2 mm. Thus the mean diameter is about one-fifth of the height.

The turret is slightly curved.

The turret-plates imbricate adorally, and form a series of tiers. In the greater part of the turret the plates in one tier alternate quite regularly with those of the adjacent tiers. Thus the plates come to lie in definite vertical series or columns, those of one series alternating with those of the adjacent series. As the stem tapers distally the vertical series come closer together and the regular arrangement is lost. The distance between the tiers seems to become rather less as the proximal (upper) end of the turret is approached. In the upper half of the turret, i.e. in the proximal 10 mm., there are about 22 plates in vertical series, so that the usual amount of each plate exposed is about ·5 mm., a little less in the immediately proximal region, but scarcely ever more in the distal region. The number of tiers in the same distance is double, viz. 44; since there would be fewer in the distal region the total may be estimated at about 80. The number of vertical series visible in the proximal region is 5, from which a total of 10 at most may be inferred.

In spite of the regularity of tiers and columns, the wicker pattern produced is not very regular, and this is due to the ragged outline of the individual plates. Probably the adoral margin of each plate tended to form a convex curve; but the edge was thin and irregular, and has frequently been broken, so that the marginal curve is truncated.

It is quite possible that the free edge of the turret-plates supported minute spinules, but there is now no trace of such structures. At the very summit of the turret, however, lying against the outer cup-plates, are four vertical rod-like ridges; and these may represent spines.

(To be concluded in our next number.)

III.—The *Marsupites* Chalk of Brighton.

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

A DESCRIPTION on modern lines of the Brighton chalk below the (old) zone of *Actinocamax quadratus* is to be found in Dr. Rowe's "Coast Sections", pt. i, p. 346.[1] The principal points that he makes are that between Ovingdean Pumping Station and Black Rock the cliffs display below the (old) zone of *A. quadratus*

[1] Proc. Geol. Assoc., vol. xvi, pt. vi.

a thickness of 58 feet of chalk, the whole of which he assigns to his zone of *Marsupites*, and further to his *Marsupites* band as *Uintacrinus* was not found in it, but he notes that *Uintacrinus* has been found on the reefs. These points have, as far as I know, stood unchallenged hitherto, but I am unable to reconcile them with my experience.

The marl band which Dr. Rowe took as the base of the old zone of *A. quadratas* (op. cit., p. 340) can be identified beyond all question as the one which in the August number of this Magazine, p. 363, I placed $15\frac{1}{2}$ feet up in the subzone of *Echinocorys scutatus*, var. *depressus*. Below it I have measured the following section in which my own classification is indicated.

Chalk of the Brighton Cliffs below the (old) Zone of *A. quadratus*.

Zone	Bed		ft.	in.	ft.	in.
		Marl band (Dr. Rowe's base of (old) zone of *A. quadratus*).				
Zone of *O. pilula.*	8.	Chalk			6	0
		Marl band.				
	7.	Chalk			5	0
		Marl band.				
	6.	Chalk without any crinoid brachials or plates .			3	6
Zone of *Marsupites.*	5.	Chalk with a number of brachials and one plate .			1	0
		Very thin and rather uncertain marl band.				
	4.	Chalk with crinoid brachials and curious plates .			7	0
		Strong marl band.				
	3.	Chalk with *Marsupites*	15	6		
		Parting with traces of marl.				
		Chalk with *Marsupites*	10	0		
		Strong marl band.				
		Chalk with *Marsupites*	8	3		
		Pair of marl bands with intervening chalk	1	6		
		Chalk with *Marsupites*	9	6		
					44	9
		Parting and weak marl seam.				
Uintacrinus band.	2.	Hard chalk without crinoid remains			2	0
		Thick flint seam.				
	1.	Chalk with one crinoid brachial	3	0		
		Marl seam.				
		Chalk with *Uintacrinus*	4	0		
		Marl seam.				
		Chalk with *Uintacrinus*	5	3		
		Marl seam.				
		Chalk with *Uintacrinus*		6		
					12	9
		Flint seam determining the general reef level at Black Rock.				
					82	0

	ft.	in.
Zone of *O. pilula*	14	6
,, *Marsupites*	52	9
Uintacrinus band	14	9
	82	0

It will be seen that I found 82 feet of chalk exposed in the cliff, against Dr. Rowe's measurement of 58 feet, and a considerable thickness of the *Uintacrinus* band where he found none.

The whole of Bed 1 is exposed for a distance of some 150 feet from the last stone groin at Black Rock. The greater part of it then passes out of sight fairly quickly under the combined influence of an easterly dip and the rise of a shingle bank; but once the thick flint seam which forms its upper boundary has reached the shingle level it continues at about that level, appearing and disappearing, for quite a quarter of a mile before a further rise of the shingle hides it finally, so that there is a long exposure of the *Uintacrinus* band.

Bed 2 appears to be quite devoid of crinoid remains, and in accordance with my practice elsewhere I assign it to the *Uintacrinus* band.

Bed 3 embraces all the chalk yielding undoubted plates of *Marsupites.* It appears to be uniformly poor in fossils as compared at any rate with the *Marsupites* chalk of Hants and Kent, and especially so in the lower beds. The same progression in the plates of *Marsupites* from dwarf and smooth plates up to large and elaborately ornamented plates which appears to exist in Hants can be traced here, though not so well as in Kent, as noted by Dr. Rowe.[1] The retrogression in size, accompanied by intensification for a time in ornament ending in a sudden brief return to smoothness, which appears to take place in the upper beds in Hants, can be more or less recognized here also.

Bed 4 is the one which I specially discussed in the August number of this Magazine (pp. 361, 362), and which yields brachials and curious plates of crinoids. Brachials are distinctly more numerous here than is usual in *Marsupites*-chalk, but less numerous than is usual in *Uintacrinus*-chalk. They seem to me indistinguishable from those which accompany plates of *Marsupites* (and *Uintacrinus*), but after close examination of all the plates from this bed I am not able to assign one of them satisfactorily to *Marsupites.* They appear to be all more or less related, and I am left with a strong impression that they represent a third crinoid distinct from but generally resembling *Marsupites* and (in a stronger degree) our common species of *Uintacrinus*, and being possibly another species of the latter genus. If so it would not alter my view that the affinities of the bed are far more strongly with the zone of *Marsupites* than the subzone of *E. scutatus*, var. *depressus*, and that it should be included with the former. With it must go Bed 5, from which I have now a number of brachials and one of the peculiar plates. (In the August number of this Magazine I left this latter bed in the subzone of *E. scutatus*, var. *depressus*, thereby securing a physically definite boundary at what was then a very small sacrifice of palæontological principle.)

It is interesting to note that the *Marsupites*-chalk of Kent is crowned by a bed which appears to be more fossiliferous than this Sussex bed, but corresponds very closely in its fauna. The only noticeable point of difference is that *Hagenowia rostrata*, which has not yet occurred at this horizon in Sussex, is abundant there in Kent. This is, however, only what might be expected from the relative frequency of this fossil at lower levels in Kent as compared with Sussex, where I know of no specimen below the zone of *O. pilula* and only one in it.

[1] "Coast Sections," pt. i, p. 297.

A closely corresponding bed has been identified at Scratchells Bay, Isle of Wight, in spite of the very small area and unfavourable condition of the section (see the September number of this Magazine, p. 408); and the existence of a corresponding bed in Hants is fairly certain from the presence of one of the peculiar plates, with a brachial, at the base of my pit No. 885,[1] and from various instances of brachials unaccompanied by plates of *Marsupites* at points obviously on the border-line between the zones of *Marsupites* and *Offaster pilula* (notably my pit[2] No. 857). It is therefore likely that such a bed occurs uniformly at this horizon in South England, though the opportunities for putting this to a conclusive test away from cliff sections may be very few. There is hardly a single pit, e.g., in all Hants where the upper beds of the chalk with *Marsupites* can be positively identified and the succeeding beds are well exposed.

For a long time this Bed 4 was the lowest point to which I had traced any instance of the free-growing forms of *Retispinopora* (*R. arbusculum*, Bryd., and *R. patula*, Bryd.), or of *Lophidiaster pygmæus*, Spencer, and I had an uncomfortable feeling that this coincidence was a possible argument against including the bed in the zone of *Marsupites*; but this doubt has recently been dispersed by a specimen of *R. patula* found at the base of the zone of *Marsupites* (=*Marsupites*-band of Rowe) in Kent.

Beds 6, 7, and 8 I continue to assign to the zone of *O. pilula* and subzone of *E. scutatus*, var. *depressus*.

The zone of *Marsupites* here is almost as prone as the subzone above it to develop flint tabulars, mostly interstratified but never really persistent.

IV.—The Penmaenmawr Intrusions.

By H. C. Sargent, F.G.S.

The subject of this paper is a group of three intrusive masses of igneous rock, possibly laccolitic in their origin, whose outcrops are situated within a radius of a mile from the village of Llanfairfechan, on the north coast of Carnarvonshire.

The most northerly and the largest of these intrusions is the well-known Penmaenmawr Mountain (1,550 feet above O.D.), and the two others lying to the south are Dinas (1,000 feet) and Carregfawr (1,167 feet).

The petrology of Penmaenmawr has already been dealt with by several writers of eminence. The rock has been described by Phillips as a quartziferous diorite;[3] by Teall as an enstatite-diorite;[4] by Harker as in part a bronzite-bearing quartz-dolerite and in part a quartz-andesite;[5] by Hatch as markfieldite;[6] by Rosenbusch as

[1] Brydone, *The Stratigraphy of the Chalk of Hants*, p. 88; London, Dulau & Co., Ltd., 1912.

[2] Op. cit., p. 86 and (under erroneous number 859) p. 92.

[3] "On the Chemical and Mineralogical Changes which have taken place in certain Eruptive Rocks of North Wales": Q.J.G.S., vol. xxxiii, pp. 423–9, 1877.

[4] *British Petrography*, 1888, p. 273.

[5] *The Bala Volcanic Series of Caernarvonshire*, 1889, p. 64.

[6] *The Petrology of the Igneous Rocks*, 7th ed., 1914, p. 369.

enstatite-diabase;[1] by Zirkel as quartz-norite;[2] and, finally, by Schaub as an augite-bearing quartz-norite![3]

Of the two southern intrusions, the only mention the writer has found is by Harker,[4] who refers to Carregfawr as "the smaller hill half-a-mile to the south, above Tai-rhedyn".[5]

The three masses are intruded into, or perhaps have broken through Lower Ordovician shales, and the accompanying Map (Fig. 1) shows their surface relations to each other. It appears probable, judging by petrological affinities, that they owe their origin to a common intercrustal reservoir.

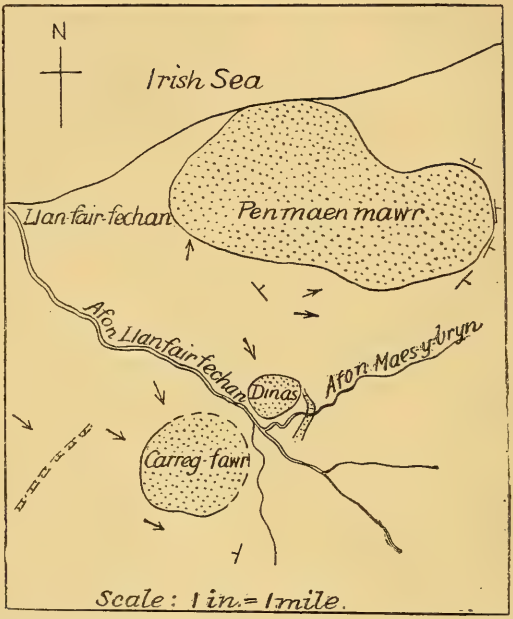

Fig. 1.—Sketch-map of Llanfairfechan District. Stippled areas, intrusive rocks; plain areas, Ordovician beds and Glacial Drift; ⊤, strike and dip of cleavage. Arrows indicate direction of dip of imperfectly cleaved beds.

On the Geological Survey Map (Sheet 78, S.E.), published in 1852, the two southern outcrops are coloured as a single intrusion, the area of which is extended very considerably to the south and east of the limits shown on Fig. 1, so far indeed as to impinge on the lowest of the lavas of Bala age.

[1] *Mikr. Phys. d. mass. Gest.*, 2nd ed., 1887, p. 204.
[2] *Lehrbuch der Petrographie*, 2nd ed., vol. ii, p. 641, 1894.
[3] "Ueber den Quarznorit von Penmaenmawr in Wales und seine Schlieren-bildungen": *Neues Jahrbuch für Mineralogie*, etc., Abh., pp. 93–121, 1905.
[4] Op. cit., p. 62.
[5] A misprint on the Geological Survey Map for Ty'n-rhedyn.

After a careful examination of the ground, the writer submits that this extension of area is not supported by field-evidence. All the valleys in the area covered by the map (Fig. 1) are so choked with drift that accurate mapping of the boundaries is impossible. The streams have nowhere cut through the drift down to solid rock, except at one point where the Afon Maes-y-bryn traverses a dyke. Here the valley is suddenly constricted so as to form a narrow gorge, and it widens out again immediately below.

The drainage system appears to have been initiated in pre-Glacial times, since the valleys were carved out pre-glacially, and it is suggested that the three streams, which unite at the foot of Dinas to form the Afon Llanfairfechan, would scarcely have cut deep channels through a particularly hard igneous rock, when in other directions a choice of soft beds was readily available. Further, the rock at the foot of Dinas on the south and south-east sides of the mountain, that is to say not far from the centre of the mass as mapped by the Geological Survey, is distinctly of the marginal type referred to below, and this is sufficient to show the improbability of Dinas having originally extended to any considerable distance beyond its present limits, in the direction of Carregfawr or of the Bala lavas on the south-east. The surface of the ground in the neighbourhood of the intrusions is strongly glaciated, in places up to 1,100 feet above O.D.; and around Dinas and Carregfawr, owing to the covering of drift, it is only here and there that the Ordovician beds are exposed.

The summit of Penmaenmawr, an abrupt conical peak, appears at a distance to rise from a level table-land at the height of about 1,100 feet above O.D. On the ground it is seen that this table-land has a very uneven surface. An abrupt ridge varying from 200 to 300 feet in height above the surface of the table-land runs round the south and east sides from Clip yr Orsedd to Graig Lwyd (Fig. 2). The central portion of this eastern lobe of the outcrop is occupied by a depression filled with drift, some of which appears to be of local origin from the east.

Around Penmaenmawr the slates are frequently exposed, and a study of their behaviour towards the intrusive rock is not without interest. Contact between the two may be seen at the entrance to the most easterly of the Graig Lwyd quarries, and the sedimentary beds have here been so intensely baked to the thickness of 4 or 5 feet that it is hard to determine in the field the precise line of demarcation between them and the intrusive rock.

In the same locality, that is to say on the east of the intrusion, the slates are more perfectly cleaved than elsewhere, with nearly vertical cleavage-dip, and as shown on the Map (Fig. 1) a close parallelism is preserved between the cleavage-strike and the boundary of the igneous rock. On the southern side the sedimentary beds are imperfectly cleaved, the dip is lower than on the east, and the parallelism is lost.

Two inferences appear to be allowable from these considerations: (1) that the pressure which produced the cleavage acted here in a more or less east to west direction with the intrusive mass as a resisting obstacle; and (2) that the intrusion is consequently older than the cleavage. The beds on the south of the intrusion could more easily yield to a pressure coming from the direction suggested, and the cleavage there would thus be less perfect. The *general* direction of the axes of disturbance that produced the cleavage over the Carnarvonshire area was S.E. to N.W., as shown by Mr. Harker.[1] Near Dinas and Carregfawr the exposures are too few and too poor to form satisfactory conclusions as to the relations of the slates to the igneous rock, though here too a similar parallelism seems to be at times approached.

Assuming, on the authority of Ramsay,[2] that the cleavage was effected "before the commencement of the deposition of the Upper Llandovery strata", it seems probable that these intrusions were contemporaneous with the great manifestations of igneous activity in Carnarvonshire, which are recognized to be of Bala age. Schaub,[3]

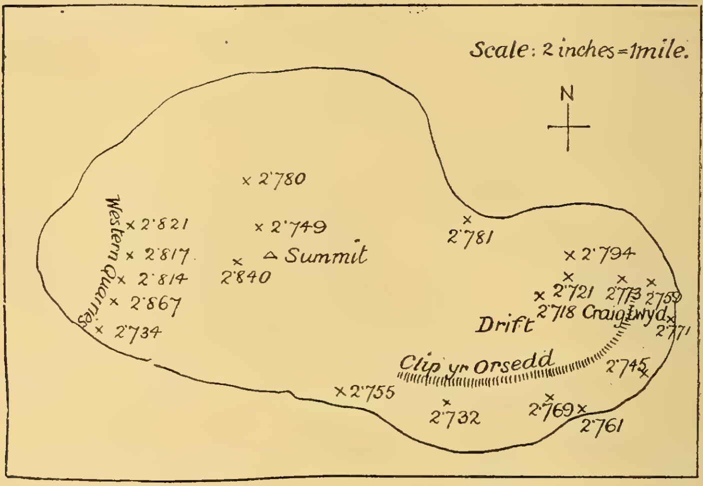

FIG. 2.—Sketch-map of Penmaenmawr.

without adducing evidence, states that Penmaenmawr is younger than Silurian and of late Palæozoic age. In the absence of evidence it is impossible to examine the reasons for this view.

The extensive quarrying operations on Penmaenmawr facilitate examination of the rock from the margin to the centre of the mass, and three distinct varieties grading into each other may be observed—(1) the marginal rock, dark-coloured, very compact, and at times somewhat cherty in appearance; this merges into (2) a fine-grained variety, rather lighter in colour, often of a bluish and sometimes of

[1] *The Bala Volcanic Series of Caernarvonshire*, 1889, p. 113.

[2] *The Geology of North Wales* (Mem. Geol. Surv. England and Wales), vol. iii, 2nd ed., p. 326, 1881. See also Harker, "Notes on the Geology of Mynydd Mawr": GEOL. MAG., Dec. III, Vol. V, pp. 221–6, 1888.

[3] Op. cit., p. 94.

a greenish tinge; this in turn passes gradually into (3) a medium-grained, light-coloured rock of speckled appearance owing to the intermixture of felspar and pyroxene phenocrysts, and the presence of a considerable amount of coarse micropegmatite. Especially towards the margin the rock is intersected by accurately parallel, platy divisional planes, in sets running in different directions and often obliterating each other. These divisional planes appear to be due to contraction on cooling.

There can be no excuse for dealing in detail with the microscopic structure of the Penmaenmawr rock, in view of what has been done by abler petrologists in this direction, but a few observations may perhaps be permitted to indicate the relationship of the different varieties to each other.[1]

The essential minerals present are, in their order of formation, bronzite; plagioclase and augite (these three occur as phenocrysts); orthoclase; quartz. Flakes of biotite also occur, as well as apatite and ilmenite as accessories. A noticeable feature of the thin sections is the progressive increase of quartz from the margin inwards, and this appears to be accompanied by decreasing basicity of the felspar phenocrysts.

The marginal rock is characterized by the presence of an andesitic ground-mass, consisting of felspar microlites with bronzite and augite in a second generation of minute crystals and grains; probably a little glass, and occasionally a small amount of quartz, some of which is doubtless of secondary origin. In places the felspar is of the allotriomorphic type. Flow-structure is frequently very marked. Among the phenocrysts, felspars are, on the whole, rather scarce, but bronzite and augite occur more frequently, the latter predominating. The bronzite is often represented here, as throughout the mass, by bastite pseudomorphs.

In the fine-grained rock the andesitic structure falls off. The ground-mass consists of felspar laths, allotriomorphic felspar, and increasing quartz; micropegmatite comes on, and in the medium-grained rock it is beautifully developed and generally forms the entire ground-mass.

Determination of the felspar phenocrysts in the marginal rock is difficult, owing to the extent to which alteration has taken place, and they are often indeterminable. The microlites of the ground-mass may be referred to oligoclase.

Thin sections prepared from the fine and medium-grained varieties allow of better determination, the felspars in the former being often quite fresh. Sections normal to the albite lamellæ show maximum extinction angles of 25° (in one instance of 30°) in the fine-grained rock. Proceeding inwards towards the centre, the extinction angles diminish to a maximum of about 20°. Schaub[2] finds extinction angles on (010) of 30°, and concludes that the species is near bytownite. In the slides examined by the writer, sections on (010) cannot often be observed, but in a slide (No. 308) prepared from the

[1] Twenty-seven thin sections of Penmaenmawr, two of Carregfawr, and five of Dinas have been examined.

[2] Op. cit., p. 96.

rock in the quarry directly under the summit such sections occur. These show extinctions of about −12°, and in one or two instances + 7° and + 10°. It may therefore be not unreasonably concluded that the plagioclase in the rock ranges from an acid labradorite near the margin to the oligoclase-andesine series in the central portion. There is no doubt that orthoclase is also present in all the varieties of the rock, but subordinate to plagioclase.

Pyroxene phenocrysts (both rhombic aud monoclinic) occur in greater quantity in the fine and medium-grained rock varieties (that is to say in the inner portion and up to the centre of the mass) than in the marginal rock. The same remark holds good locally of apatite. A section from the centre (No. 308) shows larger and more abundant crystals than have been observed in any other part.

Bronzite, whether fresh or in the form of bastite, always assumes idiomorphic outlines, generally in prismatic sections. The terminations have always a ragged and frayed appearance, the result probably of resorption. Augite is generally fresher than bronzite and shows the fine basal striation noted by Teall on both pinacoids. Schaub[1] claims that this feature predominates in brownish individuals, turbid through commencing decomposition, and that it may therefore be looked upon as a secondary appearance.

The proportions of bronzite and augite are fairly equal throughout the fine and medium-grained rock.

The predominating iron-ore appears to be titaniferous. It occurs in rectangular grains and hexagonal crystals, and often shows beautiful decomposition effects. It frequently contains enclosures of apatite, and has no doubt as a rule followed that mineral in the order of crystallization. It occurs in larger crystals and in greater abundance in the inner part of the mass than at the margin.

Veins are an important feature in the structure of Penmaenmawr. They are sometimes seen to traverse the whole face of the mountain exposed by quarrying operations (the uppermost 500–600 feet), and they vary in thickness from half an inch up to 6 or 8 inches. When fresh the vein material is of a whitish or light-grey colour, but more frequently, owing to the presence of decomposition-products, it is coloured green of varying shades.

In addition to the true veins, irregular patches and streaks with similar variations of colour are common. These often display no definite boundary, but merge into the surrounding rock, and seldom extend to any great distance. Judging from their microscopic structure, referred to below, they are of the nature of segregation-patches of the more acid constituents of the rock. When much altered they have frequently a mottled appearance, green and white, owing to the presence of large flakes of quartz in addition to the green decomposition products. Grains of secondary epidote may often be observed in hand-specimens. These veins and segregation patches appear to occur in the western quarries more abundantly in the fresh condition than the green veins, and Mr. T. H. Waller[2] paid special

[1] "Ueber den Quarznorit von Penmaenmawr in Wales und seine Schlieren-bildungen": *Neues Jahrbuch für Mineralogie*, etc., Abh., p. 100, 1905.

[2] *Midland Naturalist*, 1885, p. 5.

attention to them there, and described their structure thirty years ago. They are called by the quarrymen 'spar'. In other parts of the mass the green veins and patches are common, and the light-coloured 'spar' is nearly absent. Schaub[1] classifies and describes these veins and patches under five heads, according to their colour and grain, but, as there is no essential difference in structure, and the different varieties can be observed in the field to merge into each other in the course of a single vein, this classification seems unnecessary.

All these veins and segregation patches afford beautiful examples of micropegmatite, which forms the greater part of the vein-material. Thin sections show the presence also of orthoclase and plagioclase crystals (the latter in subordinate quantity), augite, biotite, apatite, ilmenite, and secondary epidote. There is also frequently present a colourless mineral, showing radiating structure and with high indices of refraction and double refraction, which Schaub determines as prehnite, and considers to be an alteration-product of plagioclase. On the authority of Brauns he explains its presence as follows:—[2]

Plagioclase, an isomorphous mixture of Ab and An molecules, is in respect of the Ab molecules subject to alteration into kaolin ($2\,H_2O\,.\,Al_2O_3\,.\,2\,SiO_2$).

$$Na_2O.Al_2O_3.6\,SiO_2+2\,H_2O=Na_2O+4\,SiO_2+2\,H_2O.Al_2O_3.2\,SiO_2.$$

Two An molecules, with the addition of water and the SiO_2 liberated from the Ab molecule, give prehnite ($H_2O\,.\,2\,CaO\,.\,Al_2O_3\,.\,3\,SiO_2$) and kaolin.

$$2\,(CaO\,.\,Al_2O_3\,.\,2\,SiO_2)+3\,H_2O+SiO_2=H_2O\,.\,2\,CaO\,.\,Al_2O_3\,.\,3\,SiO_2+2\,H_2O\,.\,Al_2O_3\,.\,2\,SiO_2.$$

In the green veins the orthoclase of the intergrowth, and generally also that of the phenocrysts, is altered to an aggregate of chlorite. Not infrequently the phenocrysts show only a border of chlorite, the interior being altered mainly to epidote. The plagioclase crystals in the veins are often less altered than the orthoclase. They show very fine lamellar twinning on the albite law, with low extinction angles, and may be referred to oligoclase. Bronzite appears to be absent from the veins and segregation-patches. Augite is subordinate in quantity. It rarely shows crystal outlines, and is generally represented by secondary hornblende. Biotite occurs very locally and only in shapeless grains. A little apatite also occurs locally, generally in long needles. Ilmenite is abundant and often shows good crystal outlines, with much production of leucoxene. It also alters occasionally into a semi-translucent, dark-brown substance, slightly doubly refracting, and giving indistinct biaxial effects in convergent light.

The significance of these veins has been pointed out by both Waller and Teall. To quote the latter:[3] "They are composed of the mother-liquor left after the separation of the more basic compounds." On this view, it may be assumed in the case of the true veins that fissures and crevices, the result of contraction of the cooling mass,

[1] "Ueber den Quarznorit von Penmaenmawr in Wales und seine Schlieren-bildungen": *Neues Jahrbuch für Mineralogie*, etc., Abh., pp. 111 et seq., 1905.
[2] Op. cit., p. 115. [3] Op. cit., p. 275.

were filled from below by a magma depleted of a considerable portion of its more basic elements. In the case of the segregation-patches, we have apparently a local residuum of the more acid constituents separated in the course of the consolidation of the enveloping rock. On the other hand, Rosenbusch suggests that Schaub's analyses of these veins indicate that they are the effect of decomposition rather than differentiation-products.[1] Four analyses are quoted below.

On Fig. 2, an enlarged sketch-map of Penmaenmawr, the precise spots at which specimens for thin sections were collected are shown, and the specific gravity of each specimen is given.

It might reasonably be expected that decreasing density from margin to centre would follow the progressive acidity in the same direction noted above, but, as will be seen from the figures, the reverse is on the whole the case. The rock appears to attain its greatest density in the neighbourhood of the summit and in the western quarries directly below. This is no doubt the result of greater concentration locally of the heavier minerals, especially ilmenite, bronzite, and augite, as observed above.

Alteration of minerals is of course an important factor as affecting their density, which is generally lowered thereby, through the removal in solution of heavy constituents. The variations in the density of specimens collected within a short distance of each other near the summit and in the Graig Lwyd quarries are probably the result of more or less intensive local alteration, coupled with capricious distribution of some of the heavier minerals.

The compact marginal rock shows a tolerably uniform density ranging from 2·732 to 2·771. Here too the extensive alteration noted above has probably had a lowering effect, and, as already noted, iron-ores and ferro-magnesian minerals are less abundant than in other parts of the mass. Not always, however, is alteration attended by diminution of density. In the case of the green veins where the felspars are chloritized, the specific gravity generally exceeds 2·90. Seeing that the rock before alteration consisted mainly of quartz and felspar, it is evident that there has here been an increase of density, resulting perhaps from derived iron and magnesia, which it is suggested have been liberated from the bronzite of the enclosing rock on its alteration into bastite.

Phillips, in his paper referred to above, gives analyses (of which three are quoted below) of four specimens from different parts of the mass, as evidence of progressive metamorphism by surface agencies. The present writer finds it difficult to accept his conclusions in their entirety. Phillips' "practically unaltered rock", which gave the results shown in his No. i analysis, is described as fine-grained and distinctly green in colour. It was evidently very near to the marginal rock with andesitic structure, since it was collected from

[1] "Die von Schaub mitgeteilten Analysen dieser Schlieren lassen sich kaum als Differentiationsprodukte verstehen, sondern deuten eher auf Zersetzungserscheinungen": *Mikr. Phys.*, 4th ed., vol. ii, p. 1258, 1908. [The analyses of the veins, communicated by Schaub, can scarcely be considered differentiation products, but rather suggest that they are the effects of decomposition.—Ed.]

the most westerly quarry and showed under the microscope a groundmass of felspar microlites with very little free quartz. The distinctly green colour is perhaps enough in itself to make this specimen suspect, and it has been shown above that alteration has made considerable progress in the marginal rock, especially in regard to the felspar and bronzite phenocrysts. Further, the high specific gravity (2·94) of this specimen suggests the possibility of alteration of the sort referred to in the case of the green veins.

The progressive increase of $Si\,O_2$ in Phillips' analyses appears to be attributed by him, in some degree at any rate, to its liberation from felspar as a result of alteration. In addition to his analyses, two others are given below which Mr. Eric Sinkinson, of the Imperial College of Science and Technology, has kindly prepared for this paper. Of these, one is of the compact rock on the margin of the intrusion, and the other is of the medium-grained rock from the centre. Alteration of some, at any rate, of the constituent minerals has without doubt affected the result of all these analyses, and probably none of them can be taken to represent the original unaltered rock.

The five analyses are arranged in progressive order to show the composition from margin to centre, and Phillips' analyses are also given in his order of progressive alteration. The writer submits that, looking at the analyses as a whole, they serve to confirm the microscopic examination, and that, instead of progressive alteration, they show that consolidation has to some extent followed the normal course of increasing acidity from the margin inwards. The proportion of secondary quartz seen in thin sections, which may have been liberated from the felspars, etc., is so small as not to interfere with this view.

The varying amounts of lime and magnesia may probably, to a considerable extent, be attributed to a capricious distribution of plagioclase and pyroxene, which is very noticeable in thin sections. This suggestion is perhaps confirmed by the low specific gravity of the specimens which the analyses show to be poorest in these constituents. On the other hand, it is evident that the large percentage of combined water in Phillips' No. iv analysis points to considerable alteration and the formation of hydrated silicates.

It is, however, clear from what has been said above that, in spite of the progressive acidity referred to, the course of 'fractional crystallization' has not proceeded normally. Bronzite, always the earliest formed and the most basic of the phenocrysts, is more abundant at the close of consolidation than at its commencement. The same observation holds good of both augite and apatite. It is perhaps safest not to include the iron-ores in this consideration, as they probably separate out at any stage of the process, but the rock is essentially more basic in the interior than at the margin.

Leaving, however, the consideration of this problem for the moment, it now remains to deal with the two small southern intrusions forming the mountains of Dinas and Carregfawr. No quarrying operations have been undertaken on Dinas, and it is therefore only the surface rock that can be examined and described.

The greater part of the rock as seen in the field, including that on the summit, is similar in all respects to the compact marginal rock of Penmaenmawr, and, like the latter, often breaks with conchoidal fracture. Round the base of the mountain, on the south and south-east sides, the rock is slightly less compact and is precisely similar in appearance to the transition-rock between the compact and fine-grained varieties of Penmaenmawr. It may therefore be reasonably inferred that only a limited amount of erosion has been effected by the stream sweeping round the base. On Carregfawr also only surface rock is available for examination, and it is all, including that of the summit, of the same compact type as the marginal rock of Penmaenmawr. Here, too, the platy divisional planes noticed above in the case of Penmaenmawr are well developed.

One description of thin sections will serve for the microscopic structure of the two intrusions. The minerals present are felspar, augite, and quartz, with apatite and iron-ores as accessories. Bronzite appears to be entirely absent. Felspar and augite occur as phenocrysts. The rock is much decomposed and the felspars are almost indeterminable. They appear, however, always to extinguish straight or with low angles. Augite rarely presents idiomorphic contours, but occurs mostly in the form of rounded grains. Occasionally cross-sections occur showing good outlines, the prism and pinacoid faces being equally developed. The fine basal striation on the pinacoids, noted in the case of Penmaenmawr, also occurs here. The ground-mass consists of felspar-laths, but more often of allotriomorphic felspar, and interstitial quartz. Sometimes the quartz occurs in large sheets, but never with crystal outlines. Minute grains of augite are also present in the ground-mass. Ilmenite appears to be the principal, if not the only iron-ore. It occurs in minute grains and crystals of rectangular and hexagonal outline. Generally speaking, the microscopic structure of these rocks is very similar to that of the compact marginal rock of Penmaenmawr, but quartz is on the whole more abundant here, and rhombic pyroxene as noted above is absent. The structure of the ground-mass in places may be termed sub-granophyric.

The question of the name that should be applied to the rock of which these three intrusions are composed appears to be a matter of some difficulty. The writer would naturally defer to the opinion of any one of the eminent geologists named above, of whom each has in the case of Penmaenmawr bestowed upon it a designation of his own. As it is clearly impossible to defer to them all, an independent suggestion may be permitted. It seems desirable that, if possible, the name adopted should connote not only internal structure but also mode of occurrence. Seeing that we are dealing with masses of hypabyssal habit, it will be well to discard any name properly applicable to a rock of plutonic or extrusive origin. If this be granted, we may at once rule out 'diorite', 'norite', and 'andesite'. 'Diabase' would doubtless be dismissed *sans phrase* by all British geologists nowadays.

In view of the determination of the felspars given above, and the analyses quoted below, the name 'dolerite' appears to imply a more basic rock than the one in question, which is clearly of intermediate character. Moreover, the structure is hardly doleritic, seeing that there is nothing in the rock in the nature of the ophitic habit, or to show that the felspars have on the whole crystallized out before the augite. In view of the wide structural variations shown to exist in the Penmaenmawr mass, 'markfieldite' does not seem a very suitable name for a rock, none of whose varieties agrees closely with the type-occurrence, and some of which depart from it widely.

The decks being thus cleared, it remains to suggest that since the Penmaenmawr rock is porphyritic in structure, hypabyssal in occurrence, and intermediate in composition, its essential constituents being bronzite, augite, and soda-lime felspars, it may be safely classed with the porphyrites, as has been done by Hatch,[1] and there can be no more appropriate name for it than bronzite-porphyrite.[2]

The different varieties can be distinguished by suitable prefixes. Thus at the margin we have an andesitic-bronzite-porphyrite; further inwards a quartz-bronzite porphyrite; and in the most acid variety, which clearly grades in the direction of the true granophyres, a granophyric-bronzite-porphyrite. The rock of Dinas and Carregfawr, so far as existing exposures enable us to examine it, may be termed a quartz-porphyrite.

It is to be observed, however, that in the case of Penmaenmawr a laccolitic origin is by no means established. The flow-arrangement, so pronounced in the andesitic type of the margin, and the phenomena noticed above which have attended the consolidation of the mass, are features which appear to be opposed to the view of an interbedded injection of homogeneous magma. The simultaneous injection of bodies of magma of heterogeneous composition can hardly be invoked to explain the latter feature, since the variation from margin to centre appears to be a continuous one, and there is nothing in the shape of banding or the streaked structure that would be present if such were the case.

The writer has already been perhaps somewhat too fertile in suggestions, but he will venture on one more before closing this paper.

Harker, in the fascinating chapter entitled "Review of Vulcanicity in Caernarvonshire", in the work referred to above, has pointed out the probability that volcanic action in this region manifested itself in Bala times as a result of the pressure from the south-east; "the fluid lava . . . being lifted by the pressure into the sphere of action

[1] *Text-book of Petrology*, 5th ed., p. 219, 1909.

[2] Since the above was written the writer finds that Rosenbusch was latterly inclined to take the same view. "Doch kann man es wegen seiner ausgesprochen porphyrischen Struktur nicht wohl zu den Noriten stellen. Ob man es nicht besser seiner chemischen Konstitution nach, zumal wegen seines hohen Gehaltes au Kieselsäure zu den Enstatit-porphyriten stellen sollte, darüber liesse sich streiten" (*Mikr. Phys.*, 4th ed., vol. ii, p. 1258, 1908). [One cannot, in consequence of its pronounced porphyritic structure, very well class it with norites. It is an open question if it would not be better, having regard to its chemical composition, and particularly considering the amount of silica it contains, to class it with the enstatite-porphyrites.—Ed.]

of volcanic agency, or perhaps actually squeezed out by this crust-pressure itself."[1]

If we may assume that the three intrusions discussed in this paper are the plugs of a small group of extinct volcanoes, the observed phenomena would seem capable of ready explanation.

The lighter and more acid portion of the contents of the inter-crustal reservoir would be first drained off, and it is perhaps represented by the rhyolites of the Dwygyfylchi and Y Drosgl series which are distributed round the suggested vents as a centre.[2]

If we assign Penmaenmawr and its neighbouring intrusions as the source of these lavas, the necessity of postulating an earlier volcano in the vicinity of Y Foel Fras, which "has been destroyed by a later and more extensive invasion of the igneous magma",[3] seems to be removed. Later on, the eastern lobe of the Penmaenmawr outcrop, including the Clip yr Orsedd and Graig Lwyd ridge, would be extruded, and this rock would thus constitute a true andesite, from which indeed it is indistinguishable in microscopic structure. It may perhaps be thus paralleled with the andesites of Y Foel Fras. Finally, but not necessarily at the same stage in each case, the vents would be choked with the rock forming the higher part of Penmaenmawr and the two smaller intrusions on the south.

It may be remarked that the boss-like forms of the outcrops, and the behaviour of the surrounding slates, suggest that the three masses rise more or less perpendicularly from below; and finally, they are aligned with the extinct vents lying to the south-west, Y Foel Fras and Mynydd Mawr, on the strike of the axes of disturbance that produced the folding and the cleavage of the district, and led to the outpouring of the lavas of Bala age.

PS.—It will be noted that, in the analyses of the rock, soda is always in excess of potash, thus confirming the result of the microscopic examination that orthoclase is subordinate to plagioclase. In the grey veins, which, as stated above, are comparatively fresh and in which plagioclase is subordinate, potash is in excess. In the green veins, where alteration of the felspars has proceeded much further than in the grey veins, the alkalies are strikingly reduced in quantity.

The high CaO content of the veins, as compared with the rock, is noteworthy. In the former case it appears that the lime has not been removed by alteration-processes (as has probably happened in the case of the rock), but has gone to the formation of prehnite, and its percentage is relatively increased owing to the removal of alkalies, etc.

It is to be observed that Schaub shows no combined H_2O in his analysis of the green vein (No. iv), notwithstanding the presence of hydrated silicates (prehnite and chlorite). Clearly the percentages of this analysis are relatively increased by the omission.

[1] *The Bala Volcanic Series of Caernarvonshire*, 1889, p. 120.

[2] The writer hopes to describe this series of lavas in detail in a future paper.

[3] Harker, op. cit., p. 124.

ANALYSES OF PENMAENMAWR ROCK.

	I.	II.	III.	IV.	V.
SiO_2 . .	56·13	58·45	60·31	61·75	63·75
Al_2O_3 . .	27·44	17·08	18·99	18·88	14·94
Fe_2O_3 . .	1·39	0·76	1·07	0·52	3·54
FeO . .	1·96	4·61	4·31	3·52	1·67
MnO . .	—	trace	trace	trace	—
CaO . .	4·94	7·60	5·81	3·54	5·12
MgO . .	1·93	5·15	0·83	1·90	5·95
K_2O . .	0·98	1·02	1·67	1·24	0·98
Na_2O . .	1·56	4·25	4·55	3·67	2·30
P_2O_5 . .	—	trace	trace	trace	—
FeS_2 . .	—	—	—	0·09	—
H_2O (hyg.) .	·06	0·12	0·40	trace	—
H_2O (comb.)	3·66	0·95	1·82	4·46	2·52
	100·05	99·99	99·76	99·57	100·77
Sp. gr. .	2·771	2·94	2·79	2·79	2·840

I. Compact marginal rock (Graig Lwyd Quarry). Analysis by E. Sinkinson.

II. J. A. Phillips' No. i analysis. Fine-grained green rock from most westerly quarry. (Q.J.G.S., vol. xxiii, p. 424, 1877.)

III. J. A. Phillips' No. ii analysis. Moderately fine-grained rock from most easterly quarry. Coarser than his No. i rock and less green. (Ibid.)

IV. J. A. Phillips' No. iv analysis. Rock from second quarry from west; resembles his No. ii rock, but is coarser in grain and felspar more extensively altered. (Ibid.)

V. Medium-grained rock from the centre of the mass. Analysis by E. Sinkinson.

Note.—Phillips' No. iii analysis was of rock of about the same degree of fineness as his No. i rock, and it had "evidently undergone more extensive alteration". Its content of SiO_2 was 62·24 per cent. (Op. cit., p. 425.)

ANALYSES OF PENMAENMAWR VEINS.

	I.	II.	III.	IV.
SiO_2 . .	62·70	65·1	69·53	70·42
Al_2O_3 . .	15·95	12·9	12·98	12·69
Fe_2O_3 . .	1·88	2·0	1·27	1·72
FeO . .	2·65	4·7	1·99	2·10
MnO . .	—	trace	trace	trace
CaO . .	8·46	4·7	8·87	11·34
MgO . .	3·11	2·8	1·02	0·89
K_2O . .	0·47	3·9	1·85	trace
Na_2O . .	0·57	2·8	0·94	0·23
H_2O (comb.) .	4·00	—	—	—
H_2O . .	—	1·9	—	—
Ignition .	—	—	1·29	—
	99·79	100·8	99·74	99·39
Sp. gr. .	2·940	2·72	2·687	2·945

I. Green vein from near centre. Analysis by E. Sinkinson.

II. T. H. Waller. Grey vein from western quarries. (*Midland Naturalist*, 1885, p. 5.)

III. L. Schaub. Grey vein. (*Neues Jahrbuch für Mineralogie*, etc., 1905, Abh. p. 113.)

IV. L. Schaub. Green vein. (Ibid., p. 118.)

V.—The Work of Professor Lacroix on the Laterites of French Guinea.

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Contents.

I. Introduction.

A SHORT while ago I received from Professor A. Lacroix a copy of a recently published memoir on the laterites of French Guinea, accompanied by the request that I should, if possible, give an account of this work in the Geological Magazine, "puisque c'est là qu'ont paru les articles les plus importants sur cette question." I have undertaken this task with the greater pleasure because Professor Lacroix was so good as to show me, when I was passing through Paris recently, both his hand-specimens and his microscopic preparations of these rocks, and because the memoir in question seems to me to be one of the most important and thorough pieces of work on laterite published since Max Bauer's account of the laterite of the Seychelles.[1] Although Professor Lacroix' memoir deals professedly with French Guinea only, yet it is probable that many of the conclusions will be found to apply to other regions, and on this account, and because the series in which the memoir appears will probably not be readily accessible to all, I have thought it desirable to expound it at some length.

The full title of the memoir is "Les latérites de la Guinée et les produits d'altération qui leur sont associés", the medium of publication being the *Nouvelles Archives du Musée*, sér. v, tom. v, pp. 255–356, with pls. x–xvii, 1914. It is the fruit of a visit to West Africa by the author in the winter of 1912–13, when he was able not only to explore in detail the Archipelago of Los, but also to traverse many parts of French Guinea. From Konakri on the coast to the Niger

[1] *Neues Jahrb. für Min.*, etc., ii, pp. 192–219, 1898.

Professor Lacroix followed the railway line, which provided many valuable sections; then, after examining the cuttings of a line under construction from Kouroussa to Kankan, he descended the Niger to Siguiri, which is about 360 miles in a straight line from Konakri. After touring in Bouré, a part of the ancient Sudan, he returned to Siguiri by an affluent to the left bank of the Niger, the Tinkisso, returning thence to Konakri. Professor Lacroix has also made a field study of the laterites of Madagascar on the opposite side of Africa, but he is compelled by lack of space to defer to a subsequent volume of the *Archives* an account of his work in that island.

The importance of this work on Guinea results in the first place from the fact that the author was able to examine in the field a large number of fresh sections, many of which showed the complete passage from the underlying fresh rock, through the various stages of lateritization, to the surface crust or *cuirasse*; that secondly he collected his specimens with judgment from known points in the sections, and thirdly that he has supplemented the chemical analyses (due to M. Boiteau) by careful microscopical studies of the mineralogical composition. He is thus able to trace the successive stages of change in both chemical and mineralogical composition from underlying fresh rock to surface crust. His results are rendered the more convincing by a splendid series of plates showing the field relationships (twelve photos), the aspect in hand-specimens (twelve photos), and, finally, the microscopic appearance (twenty-four photos).

II. Nomenclature.

In an introductory chapter Professor Lacroix discusses the nomenclature of the subject. After referring to Buchanan's original definition and the demonstration of Van Bemmelen [1] and Max Bauer [2] that laterites rich in hydrates sometimes contain a considerable quantity of silicates of aluminium, without differing in any way in external characters from laterites quite free from silicates,[3] he concludes (p. 258)—

> "Enfin, de véritables argiles, de vrais kaolins, abondent sous les tropiques, et ils sont, eux aussi, souvent colorés en rouge par de l'oxyde de fer."

The author then arrives at the following definition of laterite (p. 259):—

> "Les produits de décomposition de toutes les roches, silicatées alumineuses caractérisés, au point de vue chimique, par la prédominance de hydroxydes d'aluminium et de fer, avec généralement de l'oxyde de titane, après élimination plus ou moins complète des autres éléments de la roche fraîche: alcalis, chaux, magnésie et silice":

this definition agreeing with that now generally accepted.

[1] *Arch. néerl. Sc. exactes et nat.*, xv, pp. 294–305, 1910.

[2] *Neues Jahrb. Min. u. Pet.*, Festband, 1907, pp. 33–90.

[3] For the frequent difficulty or impossibility of distinguishing laterites from some clays in the absence of chemical examination, see Sir T. H. H. Holland, in the discussion on Mr. J. M. Campbell's paper on "The Origin of Laterite", Trans. Inst. Min. Met., xix, p. 455, 1910, and L. L. Fermor, Geol. Mag., 1911, p. 510.

Professor Lacroix next prints in full the tabular classification for laterites and some other surface rocks drawn up by me in 1911.[1] Putting aside for the time my terms *lake laterite*, *lateritoid*, and *lateritite*, he accepts my classification for the group "des latérites proprement dites", with certain reservations necessitated by the characters of the rocks studied.

In the first place he joins together my divisions I (lithomarge, clay, soils, etc.) and II (lateritic rocks) in order to avoid too much detail[2]; and with reference to *quartzose laterites* he thinks it more logical to base the divisions, not on the composition of the rock taken as a whole, but "sur ses éléments néogènes" only. He therefore subdivides laterites carrying quartz, not according to the total tenor in lateritic constituents, but according to their richness in these latter after deducting quartz of primordial origin.[3]

Professor Lacroix then brings forward a much more important modification or rather improvement of my classification, which is based on chemical and not on mineralogical composition. He writes (p. 261)—

"Pour rester dans les principes généraux de la pétrographie, il est donc indispensable de tenir compte de cette composition minéralogique, et *le but principal de ce mémoire* [italics mine] est précisément d'apporter des documents nouveaux à ce point de vue. En conséquence, il faut faire intervenir dans la classification la notion de l'état, cristallin ou colloïdal, dans lequel se trouvent les constituants néogènes (hydrates et silicates)."

Professor Lacroix considers the physical state of the hydroxide of iron as of no importance from the point of view of classification, because the two phases *limonite* (crystalline) and *stilpnosiderite* (colloidal) are rarely completely separated. The hydrates of aluminium, on the other hand, occur either as gibbsite or in the colloidal state.[4]

In my paper already cited (l.c., p. 561) I advanced reasons for avoiding the custom of several authors in regarding *laterite* and *bauxite* as synonymous terms, and suggested the necessity of restricting the term *bauxite* to the varieties of laterite sufficiently rich in Al_2O_3 to be used as ores of aluminium. Even this restriction is not sufficient for Professor Lacroix (p. 262)—

"Puisque la bauxite—au moins celle qui a servi de type et qui constitue tous les gisements français—est caractérisée, ainsi que je l'ai montré depuis longtemps,[5] par l'absence complète de produits cristallisés."

Consequently he qualifies as *gibbsitic*[6] (*gibbsitique*) those laterites

[1] "What is Laterite?": Geol. Mag., N.S., Dec. V, Vol. VIII, p. 514, 1911.

[2] There seems to be no good reason why we should exact less precision in naming products with less than 50 per cent of lateritic constituents than with products containing more than 50 per cent. Indeed, greater possibilities of variation amongst the former group necessitate greater precision rather than less.

[3] The undesirability of this course is indicated by consideration of the case of *latérite d'alluvions* noticed in Section IV.

[4] This can be regarded only as a general statement, for examples of the crystalline and colloid forms occurring together are given later in the memoir.

[5] *Min. de la France et de ses colonies*, iii, p. 342, 1901.

[6] Throughout this memoir the author uses the term *hydrargillite* rather than *gibbsite*, but in the adjectival form he prefers *gibbsitic* as being less cumbrous.

containing $Al_2O_3 . 3H_2O$ in the crystalline state, and as *bauxitic* (*bauxitiques*) those containing only colloidal hydrates.[1]

Then, considering the silicates of aluminium found in the laterites of Guinea, Professor Lacroix finds that they exist sometimes as crystalline *kaolinite* and sometimes as *halloysite*, the latter being either more or less crystalline or completely colloidal. He regards it, therefore, as impossible to unite all these products under the term *lithomarge* as proposed by me (l.c., p. 511), because I have suggested that lithomarge is the colloidal variety of kaolinite. This criticism seems to me perfectly valid, but see the next paragraph; the author then summarizes his conclusions in the following scheme of nomenclature, with which I agree in most respects, the mineralogical precision introduced being a very acceptable improvement:—

DIVISIONS basées sur la composition chimique.	SUBDIVISIONS basées sur la composition minéralogique.	
		Hydrates d'alumine.
I. Latérites ($Hydrates \geqq 90$, p. 100).	*Gibbsitiques.*	Cristallisé (hydrargillite).
II. Latérites silicatées ($Hydrates = 90$ à 50, p. 100).	*Bauxitiques.*	Colloïdaux.
		Silicates d'alumine.
III. Kaolins, argiles latéritiques ($Hydrates < 50$, p. 100).	*Kaoliniques.*	Cristallisé (kaolinite).
	Argileuses.	Cryptocrystallins ou colloïdaux.

Each of these types should be qualified by *quartzose* (*quartzifère*) when it contains primary (*ancien*) quartz.

It will be seen that Professor Lacroix uses the term *argileuse* instead of the adjectival equivalent of *halloysite*, with which he identifies the cryptocrystalline and colloidal silicates present. It is interesting to note that other authors have referred the colloidal silicate to the same substance. Thus Bauer[2] regards it as a "Halloysite ähnlichen Aluminiumhydrosilikat"; whilst Mr. E. S. Simpson[3] speaks of "halloysite (amorphous $Al_2O_3 . 2SiO_2 . 2H_2O$)". Halloysite is an indefinite colloidal substance corresponding to the kaolinite formula with additional water, and may itself prove to be the colloidal form of kaolinite, with this additional water in a state of adsorption or solid solution, like a portion of the water of zeolites. Dana in his *System of Mineralogy* divides the old term *lithomarge* between kaolinite and halloysite, retaining it for the firm and compact form of kaolin. If, however, halloysite prove to be related to kaolinite in the way suggested above, then obviously the term lithomarge will be a very convenient one to use for cryptocrystalline and colloidal clays in which the ratio $Al_2O_3 : SiO_2$ is 1 : 2 with a water content varying from that of kaolinite to that of halloysite. I was probably

[1] This nomenclature appears at first sight to be heterogeneous, because gibbsite is a mineral and bauxite a rock (according to Lacroix himself); but this use of *bauxitic* must be taken as analogous to that of *lateritic*, and as referring to the presence of bauxitic constituents. It is doubtful if it will be possible thus to restrict the use of the term bauxite outside the realms of mineralogy and petrology, because for economic purposes we have available no other inclusive term, except *aluminous laterite* or *aluminium-ore*.

[2] *N.J. Min. u. Pet.*, Festband, 1907, p. 87.

[3] "Laterite in Western Australia": GEOL. MAG., 1912, p. 400.

wrong in attempting to restrict the term to the colloidal form of kaolinite. The term lithomarge has long been used in the literature of Indian geology for the variegated clays so often underlying the Indian laterites,[1] and has by several decades the priority over halloysite in application to these clays, and it seems therefore desirable to me to retain it in this connexion. Perhaps in the same way as bauxite has been shown to be a rock rather than a mineral, lithomarge must be so regarded. In fact, we might regard lithomarge as related to kaolinite and halloysite in the same way as bauxite is related to the minerals gibbsite and the alumogels (see *infra*).

With this definition of the term lithomarge we may translate and re-arrange Professor Lacroix' improved classification as follows:—

DIVISIONS, based on chemical composition.	SUBDIVISIONS, based on mineralogical composition.
Laterites (L.C. $\geqq$ 90 per cent)	Gibbsitic laterites. Bauxitic laterites.
Argillaceous laterites (L.C. = 50–90 per cent)	Kaolinic / Lithomargic[2] > gibbsitic laterites. Kaolinic / Lithomargic[2] > bauxitic laterites.
Kaolins, lateritic clays[3] (L.C. < 50 per cent)	Gibbsitic clays. Bauxitic clays.

After closing his introduction with a short *historical résumé* of the previous work on the laterites of Guinea,[4] Professor Lacroix deals in four chapters with the following subjects: (i) The products of

[1] Thus in the publications of the Geological Survey of India it is used by W. T. Blanford as early as 1859; see "Note on the Laterite of Orissa" (Mem. Geol. Surv. Ind., i, p. 286). Blanford clearly distinguishes between the overlying laterite and the underlying lithomarge produced by the decomposition of gneiss. He writes: "The underlying form varies so much in constitution according to the rock from which it is derived, that scarcely any petrological term will include all its varieties. As a rule, however, it is, when derived from gneiss or other felspathic rock, a more or less ferruginous clay varying in purity. To such substances the name *Lithomarge* has frequently been applied, and it seems the most applicable in the present instance, it being understood that all the impure varieties derived from quartzose metamorphic rocks or sandstone are here included in the term." He notes the "apparent passage of Lithomarge into Laterite", but gives a different explanation from that of Professor Lacroix.

[2] By using the term *lithomargic* where Lacroix uses *argileuse*, we have the adjective *argillaceous* or *argileuse*, available as a comprehensive term, including both 'kaolinic' and 'lithomargic'.

[3] I prefer the term *lateritic constituents* (L.C.) to *hydrates*, because, at the surface, laterite sometimes contains the anhydrous mineral *hematite*, developed as a result of dehydration.

[4] In which, by the way, the author overlooks Mr. J. Morrow Campbell's paper entitled "The Origin of Laterite" (Trans. Inst. Min. Met., xix, pp. 432–57, 1910), based largely on observations made in Haute Guinée.

decomposition of the nepheline-syenites, gabbros, diabases, and peridotites (pp. 271–301); (ii) The products of decomposition of the mica-schists, gneisses, and granites (pp. 302–317); (iii) The *latérites d'alluvions* or *lateritoids* (pp. 318–324); (iv) The minerals of laterites.

It will be convenient to notice briefly the contents of chapter iv, and then to give the substance of chapter v in some detail, which summarizes admirably the subject-matter of chapters i to iii, and also gives the author's ideas as to the conditions of formation of laterite.

III. The Minerals of Laterite.

From the mineralogical point of view the most remarkable feature of lateritization is that practically all the minerals so produced are in a state of hydration, either in a colloidal phase (hydrogel) or in a crystalline phase, and most often with the two together. In certain cases it can be shown that crystallization takes place at the expense of the hydrogels, but, as related later, this is not always the case for aluminium hydrate.

Full details are given (p. 326) of the microscopic characters of the crystalline form of aluminium hydrate, namely, *hydrargillite* or *gibbsite*, which is the only crystalline aluminium hydrate found by Professor Lacroix in the laterites of Guinea, there being no evidence for the existence of *diaspore*.

The history of the *colloidal hydrates of aluminium* in laterites cannot be divorced from that of the original *bauxite*, which is only a laterite of a former period found in regions no longer tropical. As long ago as 1901 Professor Lacroix[1] showed that the French bauxites are without exception formed of colloidal hydrates, existing alone or in association with colloidal silicates, demonstrating that bauxite cannot be regarded as a mineral, because it does not correspond with the supposed specific formula of $Al_2O_3 . 2H_2O$; thus in France it has a composition approaching closer to $Al_2O_3 . H_2O$ than to any other, whilst in other regions, as in Arkansas, the composition approaches that of $Al_2O_3 . 3H_2O$. He concludes, therefore, that bauxite must be regarded as a rock composed of various colloidal aluminium hydrates mixed, according to the case, with ferric hydrates, clay, etc. Passing in review the names proposed by various authors for these colloidal hydrates, he rejects the *α-kliachite* and *β-kliachite* of Cornu,[2] the *sporogelite* of M. Kišpatić,[3] and Dittler & Doelter's use of *bauxite*, and their proposed *bauxitite*,[4] adopting the term *alumogel* suggested by M. Pauls.[5] Judging from both his own work and that of M. Arsandaux, Professor Lacroix accepts the existence of one colloidal hydrate with one molecule of water (France and Guinea), and of another with three molecules of water (Guinea and Arkansas).

Dealing with the *ferric hydrates*, he uses the term *limonite* for the crystalline form of $2Fe_2O_3 . 3H_2O$, and revives the old name

[1] *Minéral. de la France et de ses colonies*, iii, p. 342.
[2] *Zeitsch. Chem. industr. Kolloide*, iv, p. 90, 1909 (Lacroix).
[3] *Neues Jahrb.*, Beil. Bd. xxxiv, p. 518, 1912.
[4] *Centralblatt f. Min.*, 1912, pp. 19 and 104; and 1913, p. 193.
[5] *Zeitsch. prakt. Geol.*, xxi, p. 545, 1913 (Lacroix).

stilpnosiderite of Ullmann (1814) for the colloidal form of the same mineral. Details are given of the microscopic characteristics of both these minerals. The red tints often seen in the ferruginous cuirass of laterites are regarded as undoubtedly due to the dissociation of the yellow hydrate under the influence of the sun's rays. But Professor Lacroix regards the product as a mixture of *hematite* with the initial limonite or stilpnosiderite, and not as a special hydrate of formula $2\,Fe_2O_3 . H_2O$, to which the name *hydrohematite* or *turgite* has been attached. He has never detected the presence of *goethite* in the laterites of Guinea, although it has been reported as existing in some of the laterites of that country.

The *silicates of aluminium* exist in two forms, crystalline (*kaolinite*) and *colloïdal*, and of the latter the author detects two varieties, one of them cryptocrystalline, which is regarded as *halloysite*, and the other isotropic, which is supposed to possess a composition near to that of halloysite. From the fact that hydrochloric acid never breaks up more than a very small portion of the clays, he judges that there cannot be present any important quantity of silicates more basic than halloysite, such as allophane. Attempts made in Professor Lacroix's laboratory to repeat the distinction of silicates from hydrates by staining, as announced by Dittler and Doelter, gave such irregular results that they were discontinued.

It has not proved possible to detect mineralogically the presence of *titanium compounds* in laterite. But it is supposed that the portion of the titania of laterites that is soluble in hydrochloric acid exists as orthotitanic acid, $TiO_2 . 2\,H_2O$, whilst the idea of Arsandaux that the portion of the titania of laterites that is soluble only in sulphuric acid, which is the greater part, exists as metatitanic acid, $TiO_2 . H_2O$, is accepted as probable. For these titanic hydrates Lacroix proposes the name *doelterites*, in honour of C. Doelter, who has done so much work on colloid minerals.

It is supposed that the small quantities of chromic oxide detected in some laterites exist as a hydrate of Cr_2O_3, probably in the colloidal form. The only *manganiferous* product in the Guinea laterites consists of a mixture of stilpnosiderite and *psilomelane*, and was found in Los Isles.

IV. The Processes and Products of Lateritization.

In chapter v of his memoir, the author first states the *chemical result* of the formation of laterite, namely, the elimination of the alkalis, alkaline earths, and silica of the original rock, and the persistence of hydrated oxides of aluminium and iron with a little titanic acid, noticing that in different cases the rock is formed in different ways, which lead to important *mineralogical and structural variations* in the final product.

Starting from the intact rock Professor Lacroix has been led to distinguish two superposed zones, the *zone de départ*, which we may translate as the *zone of leaching*, and the *zone de concrétion*. Between the two zones there is perfect continuity, their separation being arbitrary, and necessary only for the sake of a clearer exposition of the problem; the point chosen is that where the original structure of the rock, still evident in the zone of leaching, ceases to be perceptible. More exactly the lower zone would be spoken of as the zone of maximum departure or leaching.

In the preceding chapters Professor Lacroix has discussed the products of alteration of three distinct groups of rocks, there being distinct types of laterite corresponding to each. These three groups are: (1) nepheline-syenites, gabbros, diabases,[1] and peridotites; (2) micaceous schists and granites; (3) alluvium composed of debris of non-lateritic origin. In this final chapter the author compares the three.

IV (*a*). *Zone of Leaching* (*départ*).

This zone is characterized by the elimination of the greater part of the constituents, the disappearance of which characterizes the phenomenon of lateritization; three cases can be distinguished, marked by the formation of gibbsitic laterites, ferruginous laterites, and bauxitic laterites, respectively.

Gibbsitic Laterites.—In the first case, namely that predominating in the alteration of gabbros, diabases, and nepheline-syenites, the transformation is *abrupt* without transition, the same thin slice showing the contact of the absolutely fresh rock with the portion in which there is no longer any unaltered mineral, and where the leaching of constituents destined to elimination is often almost complete.

In such rocks, the ratios of $Ti\,O_2$, $Fe_2\,O_3$, and $Al_2\,O_3$ are at first sensibly the same as in the fresh rock, but as one rises in the section the proportion of iron diminishes very rapidly in consequence of its removal to the higher levels, and later the amount of $Al_2\,O_3$ increases with reference to that of the $Ti\,O_2$.

From the mineralogical point of view the essential feature is the transformation of the felspars into gibbsite, which occupies the body of the destroyed mineral, the composition of the original felspar having no influence on the result; at the same time colloidal products take the place of the other minerals. The transformed rock, with the original structure still visible, is porous and light in weight, with a very characteristic variegated aspect, which to Professor Lacroix suggests *pain d'épices*. This laterite is more or less rich in aluminium silicate, concentrated in the skeletons of the ferro-magnesian minerals, and in the examples represented by analyses Nos. 2, 6, 9, given in Part II, the quantity of silica ranges from 2·21 to 12·67 per cent, corresponding to 5 to 30 per cent of silicate of composition corresponding to the formula $2\,H_2\,O\,.\,Al_2\,O_3\,.\,n\,Si\,O_2$.[2]

In Los Archipelago where the nepheline-syenites occur, the alteration normally corresponds with that above described, but at

[1] I have retained the term *diabase* throughout this article, although personally I think it an unnecessary term, the word *dolerite* being the more desirable.

[2] In a footnote Lacroix remarks that the essentially kaolinic transformation of a diabase is an exceptional case that he has not himself observed. Such cases occur, however, in India: cf. Mem. Geol. Surv. Ind., xxxvii, p. 376, 1909, where is described the occurrence at Yeruli of a zone of variegated argillaceous material intervening between the underlying basaltic rock and overlying laterite.

certain points in these islands it has locally pursued a totally different course, with formation of a plastic clay (see analysis No. 4, Part II). The association of these two different types of alteration is so intimate that Professor Lacroix has no explanation to offer of their coexistence at the same point (p. 281). It impels the question whether, in the normal case, gibbsite, instead of being the first secondary product formed from the felspars, may not itself have been derived from the destruction of an aluminium silicate. Judging from the examination of a considerable number of specimens in which the type of transformation is always the same, Professor Lacroix answers this question in the negative, thinking it likely that the decomposition has been from the beginning a hydrolysis of the original silicates.[1]

Ferruginous Laterites.—Ferruginous laterites in the zone of leaching result from the alteration of peridotites, owing to the poverty of these rocks in aluminiferous silicates. The ferro-magnesian silicates decompose in the same manner as in the gabbros, furnishing colloidal ferric products, containing some alumina (see analysis No. 9, Part II). The rock is porous, ochreous, light, and friable.

Kaolinic and Argillaceous Decomposition.—This, the third form of alteration in the zone of leaching, characterizes the mica-schists, gneisses, and granites. It is clearly distinguishable from the first case, because, instead of an abrupt alteration without intermediate phase, there is a *progressive change*, so gradual and extending to such a depth that the unaltered rock is seldom seen. In the mica-schists of Fatoya, borings pushed to a depth of 60 metres have not reached the fresh rock, probably because the vertical disposition of the schists has facilitated their alteration. Consequently, in contrast to the rocks considered above, in which the original structure persists for only a few metres above the original fresh rock, the *initial structure*

[1] Mr. E. S. Simpson (Geol. Mag., 1912, p. 401) has criticized adversely my postulation (Geol. Mag., 1911, p. 459) of two distinct modes of decomposition of rocks resulting respectively in the formation of clay and laterite, apparently because in Western Australia primary laterite is always found to overlie an almost pure pipeclay and this in turn a crystalline rock. From the work of Lacroix it is seen that the felspar in a crystalline rock, such as nepheline-syenite, may alter *directly into gibbsite* or *directly into a hydrous aluminium silicate.* When the latter forms, a chemical change may cease at this stage, as in Los Archipelago, or it may proceed further, as in the case of the mica-schists noticed on a later page in this paper. With reference to Mr. Simpson's comparison of lateritization with the formation of saline efflorescences, Lacroix' work indicates a marked distinction. A saline efflorescence is deposited *on* the surface of the ground; the constituents of a lateritic crust, on the other hand, are partly *residual* (although recrystallized), formed approximately in their present place from the once fresh primary rock, at the time when the zone of leaching was at this level; and have partly been brought up from the zone of leaching and added to the residual portions: in any case these constituents were deposited *inside* the crust and not *on* the surface, except perhaps to a very minor degree. In the following paragraph Mr. Simpson gives a curious definition of a *replacement of a rock*, namely, "a deposit accumulating in the actual space originally occupied by the solid rock which has yielded the materials which compose the laterite." Surely the essential feature of replacement is that the replacing mineral has been brought from elsewhere, and has been deposited in the place of another mineral removed in solution.

is here preserved through a very great thickness of altered rock; but the degree of cohesion of the rock is profoundly modified, the rock being unctuous to the touch and friable when dry. The micas are progressively deprived of their alkalis concurrently with the fixation of a larger and larger quantity of water (see analysis on p. 306 of Lacroix' memoir). From this results kaolinite or colloidal silicates of aluminium, mixed with a greater and greater quantity of aluminium hydrate. This mode of alteration also characterizes certain granites and gneisses in Guinea. None of these products of alteration in the zone of leaching would be designated laterite; they are fundamentally *kaolins* or *clays*, passing upwards into *lateritic clays*.

The type of alteration is not characteristic of a given rock.—Judging from the results given above, one might think that in the Tropics the mode of alteration of the rocks is always determined by the mineralogical and chemical composition of the original rock. Such a generalization would be inexact, as is shown by observations made in Madagascar, where the gabbros, diabases, and nepheline-syenites behave as in Guinea, but where the granites and gneisses give rise not only to a great development of argillaceous alteration products, as in Guinea, but also in places give rise to gibbsitic laterites, often quite free from iron.

(To be continued.)

REVIEWS.

I.—Water Reptiles of the Past and Present. By Professor S. W. Williston. pp. 251, with 131 text-figures. Published by the University of Chicago Press: Agents in Great Britain, the Cambridge University Press, Fetter Lane, London. Price 12*s*. net.

In this volume Professor Williston has endeavoured to give a popular account of the various groups of reptiles which have become more or less adapted to an aquatic life, and to a great extent he has succeeded in this difficult task. At the same time it is not easy to tell how far a work of this kind will appeal to the general reader, since much that is highly technical and unfamiliar necessarily remains. In any case, the book is a valuable one because it brings together in a compact form a large amount of information hitherto widely scattered and often not easily accessible.

In the earlier chapters the author gives a general account of the mode of occurrence of fossil reptiles, of their classification and their osteology. The chapter dealing with the last-mentioned subject might perhaps have been extended with advantage, and, indeed, if so good an authority as Professor Williston would publish a volume on the osteology of the class, it would fill one of the most notable gaps in palæontological literature. The subject essentially is one for the palæontologist, since in perhaps no other group of the Vertebrata are the fossil forms of such preponderating importance. This will be understood when it is realized that out of the fifteen orders into which the Reptilia may be divided no less than eleven became extinct before the end of the Secondary Period.

In the succeeding chapters an account is given of the distribution in time and space of the extinct forms, together with a very clear account of the different modifications undergone in the various groups in the course of their adaptation to an aquatic mode of life: the chapter dealing with this subject is perhaps the most generally interesting in the book.

The remainder of the volume is occupied by a series of chapters on the different orders in which some or all of the members have adopted an aquatic life. These orders are: the Sauropterygia; the Anomodontia, among which *Lystrosaurus* seems to have been at least semi-aquatic; the Ichthyosauria; the Proganosauria; the Protorosauria; the Squamata; the Thalattosauria; the Rhynchocephalia; the Parasuchia; the Crocodilia; and, finally, the Chelonia. The author, naturally, where possible refers to American types to illustrate his points, and most of the illustrations, which include numerous restorations, are likewise of American species.

This book should certainly be read by all who are interested in reptiles, living or extinct, for, although especially devoted to aquatic types, it gives a good idea of the immense diversity of form that has been attained by members of the class.

C. W. A.

II.—Reptiles and Batrachians. By E. G. Boulenger, F.Z.S. pp. 278, with 79 photographic plates (one coloured) and 25 text-figures. London: Dent & Sons, Ltd. Price 16*s.* net.

ALTHOUGH this book refers almost exclusively to living reptiles and batrachians, and more especially to their habits, nevertheless it is of considerable importance to the palæontologist, since a knowledge of the habits of recent forms is often valuable in giving suggestions for the explanation of peculiarities in the structure of extinct types. Mr. E. G. Boulenger, as Curator of the Lower Vertebrates at the Gardens of the Zoological Society, has had exceptionally good opportunities for observing the habits of the animals in question, and he has made use of them in this volume. The illustrations are for the most part a series of fine photographs, mostly taken from the life of Mr. W. S. Berridge, F.Z.S., and excellently reproduced.

III.—Mineral Resources of the United States, Calendar Year 1913.

THIS valuable work is now issued by the Geological Survey in instalments, chapter by chapter, in order to secure promptitude of publication. It is divided into two parts, dealing respectively with Metals and Non-metals. The pagination of the chapters in each is consecutive, and title-pages, tables of contents, and indices are supplied to those wishing to assemble and bind together the component chapters. Although compiled from the point of view of the United States, the work appeals to all interested in the commercial application of minerals, and contains much valuable information on the mode of occurrence, the treatment of the ores, and the uses to which the products are put. Statistics are given of the production of the various minerals and the exports and imports in the case of the United States, and often the figures for other countries are added.

In the chapter on Bauxite and Aluminium the Serpek process for fixing nitrogen by means of bauxite is described. The reaction is of the type $Al_2 O_3 + 3 C + 2 N = 2 Al N + 3 C O$, the aluminium nitride yielding with water ammonia and alumina, the latter in a very pure form. In another chapter an alloy of nickel, chromium, and copper is described which withstands the solvent action of strong acids. The chapter on the recovery of secondary metals reveals the remarkable dimensions which the treatment of scrap metal has reached, nearly seventy-three million dollars worth of metal being recovered in the United States, and that exclusive of gold, silver, platinum, and iron. A new mica product, which has been put on the market under the name 'micarta' by the Westinghouse Electrical and Manufacturing Company, is a tan-coloured, hard, and homogeneous material which can be sawn, milled, and threaded, and does not warp to any appreciable extent. One grade of it, 'bakelite micarta,' is infusible, and insoluble in nearly all the ordinary solvents. We notice on turning over the pages what a large variety of minerals are used in the decorative arts, the textile industry, and paper manufacture.

IV.—Middle Triassic Marine Invertebrate Faunas of North America. By J. Perrin Smith. Professional Paper No. 83 of the United States Geological Survey. 4to; pp. 148 and 99 plates. 1914.

MR. J. PERRIN SMITH'S memoir on the above is a handsome and well-illustrated survey of three orders of Cephalopoda (Ammonoidea, Belemnoidea, and Nautiloidea) and some genera of Lamellibranchia, Brachiopoda, and Crinoidea. The work forms the second part of a series of three volumes on the marine invertebrate faunas of the Lower, Middle, and Upper Trias of North America which continues and supplements a previously published work by the same author, consisting of a synoptical introduction to the whole fauna. Professor Alpheus Hyatt and Mr. Smith originally proposed to produce a joint monograph on this subject, but owing to Professor Hyatt's advanced age the project was not proceeded with, and ultimately Mr. Smith's introduction, in the preparation of which he had Professor Hyatt's assistance, was substituted, appearing as Professional Paper No. 40 of the Survey.

The present work will be mainly interesting to the general student (apart from the specialist) for its excellent summary of the relationship of the fauna of the Middle Triassic seas of North America to those of the Eastern Hemisphere. Mr. Smith's conclusion on this question is that the kinship between the American and Mediterranean faunas is closer than that between the American and Asiatic. In addition to the strictly systematic portion in which two new genera and many new species are described there is a short and vivid description of the geography of Triassic North America, and a table giving the interregional correlation of the Triassic areas. The work is copiously illustrated with ninety-nine quarto plates.

V.—Fauna of the Spiti Shales.

THE report upon the fauna of the Spiti Shales is continued in *Palæontologia Indica* by pt. ii of vol. iv (4to, pp. 397–456, pls. xciv–c), in which Dr. Karl Holdhaus contributes a study (translated by Mr. E. W. Vredenburg) of the Lamellibranchia and Gastropoda.

Dr. Holdhaus describes a new and interesting genus, *Cosmomya*, the precise systematic position of which is doubtful, and about twenty new species of Lamellibranchia. The Gastropoda from the Shales are poorly represented, a new species of *Pleurotomaria*, a poorly preserved *Cerithium*, and the cast of an indeterminable form being the only material available for study. Careful and exhaustive descriptions of the new species are given, and Dr. Holdhaus enters a plea for full and correct descriptions in palæontological literature.

As the author points out, the Lamellibranchia do not possess the same importance from the stratigraphical point of view as other groups of animals, and in this case they do nothing more than endorse the conclusions based on a study of the Ammonites. A few forms point to Upper Jurassic age for the Shales, but on the whole the Lamellibranchia supply no precise indications of age. Dr. Holdhaus treats the faunistic relations of the group with caution. He restricts himself to inferring a possible connexion with the Jurassic faunas of Europe, but points out the occurrence of forms which may indicate other affinities, for instance with Somaliland and Arabia. He also ventures to suggest a close connexion with the Jurassic of Kachh, though he admits that the Lamellibranch fauna of the latter is as yet imperfectly known. On the whole, the Spiti Shales Lamellibranchia appear to be eminently specialized, and, with due qualifications, Dr. Holdhaus states that he is unable to point to a single species (with the exception of some species of *Astarte* with possible Kachh relationships) as truly identical with the fossils of other Jurassic regions.

VI.—Crinoids and Dolomite. By F. W. Clarke and W. C. Wheeler.

MESSRS. F. W. CLARKE and W. C. Wheeler (United States Geological Survey, Professional Paper 90–D; June 16, 1914) have followed up observations made by H. W. Nichols (1906) and A. H. Clark (1911), and have analysed the skeletons of specimens belonging to nineteen genera of recent crinoids. As in the previous cases, all contained magnesium carbonate in proportions varying from 7·28 to 12·69 per cent. The available data show a general increase of this constituent with increase of temperature in the water, but the reason for this relation is not clear. The skeletons of ten fossil crinoids, ranging from Lower Ordovician to Eocene, were also examined, but, with one exception, showed a very small percentage (·8 to 2·56) of magnesium carbonate. The alteration is ascribed mainly to infiltration by calcium carbonate and other constituents, which would naturally lower the proportion of magnesium carbonate. The original suggestion, therefore, that crinoids might play an important part in the formation of magnesian limestones is far from being supported. Nor is it supported by the sole exception, for this was a stem of the common Lily Encrinite from the Muschelkalk; and the reason that this had no less than 20·23 per cent of magnesium carbonate is presumably that it came from one of the many Muschelkalk limestones that have been dolomitized. Even so the proportion of magnesium carbonate does not come near that which obtains in true dolomite.

VII.—Professor E. S. Morse on an Early Stage of *Acmæa*.

PROFESSOR EDWARD S. MORSE'S paper (Proc. Boston Society of Natural History, February, 1910) on "An Early Stage of *Acmæa*", though delayed in coming into our hands, deserves even a late appreciation. Contributions to our knowledge of the phylogeny of the Mollusca are exceedingly desirable, and we wish students of this phylum would spare more time from systematic conchology to the study of such problems as Mr. Morse deals with in his paper. The author, after a study of two species of *Acmæa*, in which (in one at least) no trace of a coiled Nautiloid apex was found in the embryonic stage (though such a coiled apex has been found in the early stages of other Docoglossa), proceeds to review some of the evidence (palæontological, embryological, and anatomical) that suggests that the Docoglossa are actually primitive Gastropoda. It is plain, of course, that all the members of the sub-order (*Lepeta*, *Pilidium*, *Helcion*, etc.) must be examined before we attempt to formulate any final statement as to the evolutionary status of the Docoglossa, and in the meantime such evidence as Mr. Morse is able to produce is most valuable, if not actually sufficient to upset the belief that the Docoglossa are not entirely primitive in their structure.

VIII.—Brief Notices.

1. In a paper recently published in the Smithsonian Miscellaneous Collections (vol. lx, No. 21) J. W. Gedley records the occurrence of a bone of a camel associated with remains of the mammoth and bison, from a locality in the Yukon Territory, Alaska, some distance within the Arctic Circle. Although, as is well known, the Bactrian Camel can endure extreme cold, no remains of any member of this group have hitherto been found nearly so far north.

2. Chalk of Gingin, Western Australia.—Mr. R. Etheridge has issued as Bulletin No. 55 (1913) of the Geological Survey of Western Australia a description of the fossils of the Gingin Chalk. The fauna shows a striking similarity to the uppermost White Chalk of England, with *Magas* and *Trigonosemus*. In Bulletins Nos. 36 (1910)

and 50 (1912) the stratigraphy of this deposit was dealt with by Messrs. Glauert, Maitland, and Montgomery.

3. Cambrian Stratigraphy in the North American Cordillera. —Mr. L. D. Burling discusses the *Albertella* fauna, and shows that it is unassociated with *Olenellus*, and consists of forms either typical of Middle Cambrian or confined to the *Albertella* fauna, as species of unknown or connecting affinities. The lower Middle Cambrian boundary has now been drawn at the base of such horizons as the one containing the *Albertella* fauna. (Mus. Bull. 2, Dept. of Mines, Canada, 1914.)

4. Geology of Long Island.—An elaborate and detailed description of the geology of Long Island is provided by M. L. Fuller as Professional Paper 82, Department of Interior, United States Geological Survey, 1914. The paper is fully illustrated by sections and topographic maps. As there is a large amount of Quaternary and Glacial deposit on the island, the work may be studied with profit by many English geologists quite apart from its general interests in a stratigraphical direction.

5. Transportation of Debris by Running Water.—G. K. Gilbert and E. C. Murphy, in dealing with the subject of transportation by running water, discuss the apparatus employed, adjustment of observations, relation of capacity to slope, relation of capacity to form ratio, of capacity to discharge, to fineness of debris, to velocity, to depth; experiments with mixed grades, with crooked channels, flume traction, natural streams, rhythm. (Professional Paper 86, Department of Interior, United States Geological Survey, 1914.)

6. Note on the Temperature in the Deep Boring at Findlay, Ohio. By John Johnson. Amer. Journ. Science, vol. xxxvi, pp. 131, 1913.

The temperatures of the borehole were measured by maximum reading thermometers, three thermometers in a copper cage being used for each measurement. The total depth of the boring was 2,980 feet, and throughout the lower 2,000 feet the gradient was determined to be practically uniform, viz. 0·41° C. (0·74° F.) per 100 feet. Gas flows through the rocks down to a depth of 770 feet, and, as might be expected, the expansion of this gas when it reaches the borehole results in cooling. Consequently the temperatures measured down to that depth are uniformly too low, being those of the expanding gas, and not those of the adjacent rocks.

7. The Grand Gulch Mining Region, Mohave County, Arizona. By James M. Hill. United States Geological Survey, Bulletin 580–D. pp. 58. Washington, 1914.

The copper-ore bodies occur around the side of a vertical mass of sedimentary rocks lying within a series of stratified rocks. The original sulphides have been largely converted into carbonates. The metals appear to have been brought to their present position by generally downward moving waters, which were probably cold, since no hydrothermal alteration of the wall rocks in the vicinity was noticed.

REPORTS AND PROCEEDINGS.

I.—Zoological Society of London.

November 24, 1914.—Professor E. A. Minchin, M.A., F.R.S., Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

Dr. R. Broom, C.M.Z.S., exhibited the skull of a new type of Thecodont Reptile from the Upper Permian beds of South Africa, and a number of skulls of *Trichosurus vulpecula*, *Phascolarctus cinereus*, *Chrysochloris hottentota*, and *C. asiatica*, illustrating dental variations.

Dr. C. W. Andrews, F.R.S., F.Z.S., communicated three papers by Mr. D. M. S. Watson.

The first paper contained the description of a new reptile from the Permian of the Cape Province, South Africa, which Mr. Watson regards as derived from a Cotylosaurian ancestor and as perhaps related to *Aræoscelis* and the modern lizards. A new genus is founded for the reception of the so-called '*Proterosaurus huxleyi*'.

In the second paper the origin of the Chelonia is discussed, and a number of reasons given for supposing that they may be descended from some such form as *Eunotosaurus africanus*, Seeley.

In the third paper Mr. Watson describes the skulls of *Bauria*, *Microgomphodon*, and *Sesamodon*, and discusses the relation of the group with the Cynognathids. He also describes a new skull of *Lycosuchus*, in which both the prevomers and vomer are present.

II.—Geologists' Association.

On *December* 4, 1914, at University College, Gower Street, W. C., the President (George W. Young, F.G.S., F.Z.S.) in the chair, the following lecture was delivered :—

"The Fossil Flora of the Pettycur Limestone." By W. T. Gordon, M.A., D.Sc., F.R.S.E.

Several localities are known where rocks of Lower Carboniferous age have yielded petrified plant remains, but nowhere has such a variety of types been obtained as at Pettycur, near Burntisland. Here the sediments are of Calciferous Sandstone age, but the great bulk of the rocks are of igneous origin, and the plant petrifactions, preserved in lime or silica, occur in the igneous rocks either separately or in masses.

The rocks have been very vesicular, show pillow structure, and are much decomposed. Round the petrified masses ashy material is always present, and it is possible that we have a set of mud lavas into which later injections of fresh material have been forced.

The decomposition of the ashes—in which there were numerous limestone fragments—gave rise to solutions of calcareous and siliceous material by which vegetable fragments enveloped in the ashes became petrified. Volcanic ashes here, and probably in other districts also, offer opportunities for palæobotanical research of great importance.

III.—Geological Society of London.

December 2, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Age and Character of the Shippea Hill Man." By Professor T. McKenny Hughes, M.A., F.R.S., F.G.S.

The author first gives a general description of the skeleton, and of the position and circumstances in which it was found. He then discusses the mode of formation of the deposit in which the remains occurred, and the limits within which, from that point of view, we may speculate as to their age. He considers that the Pleistocene deposits of the Fenland were laid down in a gradually depressed river-basin behind a breached seaward barrier, and gives examples from adjoining areas of similar geographical conditions.

Gravels of the age of *Elephas antiquus* and *Rhinoceros merckii*, as well as gravels of the age of *Elephas primigenius* and *Rhinoceros tichorhinus*, occur within the Fenland; but they are easily distinguished from the gravels which are sometimes associated with the peat and clay, and pass under them. The fauna also of the peat and clay deposits is quite different. This area was gradually depressed, and the conflict between the upland waters and the sea went on through both the ages just referred to, as shown by the earlier *Corbicula* Bed of March and the newer Cockle Bed of Littleport.

In an embayed part of the Fen, close behind the island known as Shippea Hill, the skeleton was found in the peat, a few inches above the clay which the author considers to be the equivalent of this Littleport Cockle Bed. When first dug out the skull was in fragments, and the calotte, with its prominent brow-ridges, suggested to many a greater affinity to the Neanderthal type, and a greater antiquity than appeared probable when the rest of the cranium was added to it.

In a preliminary notice published by the author, he claimed that it could not be older than Neolithic, and suggested that it might be even as late as the time of the monks of Ely, who had a retreat on the island close by.

The author, in reply, said that they had of course been on the look-out for evidence of interment; but, as he had explained in the paper, there was none.

The comparison of the conditions of the Wash with those of the Baltic showed that the Wash was an area of depression during those later ages of which he was speaking; whereas, in later times, the Baltic was an area of elevation by which it was gradually cut off from the open sea, so that the excess of fresh water poured into it had made the eastern water now so little salt that he had seen cows drinking on the shores of the Gulf of Finland. As to the statement that the depression of the area of the Wash was entirely pre-Roman, he did not himself know of any satisfactory evidence leading to that conclusion; but that the Romans did something towards the reclamation of the Fens was suggested by the Roman remains along the bank running through the peat from Reach to Upware, and by the evidence offered by Lord Peckover as to the Roman work on the seabanks north of Wisbech. He did not think that it could be maintained that the Fenland was ever uninhabitable or uninhabited, although, until the marshy and peaty portions had been reclaimed, it was only the gravel-spurs and islands that were occupied. Crowland, for instance, was built on a gravel-bed.

2. "On a Bone Implement from Piltdown (Sussex)." By Charles Dawson, F.S.A., F.G.S., and A. Smith Woodward, LL.D., F.R.S., Pres. G.S.

During the past season the authors have continued excavations in the Piltdown gravel round the edge of the area previously explored. Rolled fragments of highly mineralized teeth of *Rhinoceros* and *Mastodon* were again found, but no human remains were met with. The most important discovery was a large bone implement, which is now described. This specimen was found in dark vegetable soil beneath the hedge which bounds the gravel-pit, not far from the spoil-heap whence the right parietal bone of the Piltdown skull was obtained two years ago. On being washed away the soil left no stain on the bone, which was covered with firmly adherent yellow clay, closely similar to that of the flint-bearing layer at the bottom of the gravel. The bone itself is highly mineralized, and agrees exactly in appearance with some small fragments of bone which the authors discovered actually in place in the clay just mentioned. There can be no doubt therefore, that the implement was found by the workmen when they were digging gravel from the adjacent hole, and was thrown away by them with the other useless debris. It is a stout and nearly straight narrow flake of bone, 41 cm. long, and varying from 9 to 10 cm. in width, with the thicker end artificially pointed, the thinner end artificially rounded. It appears to be a longitudinal strip flaked from a limb-bone by a blow at the thicker end, in the same way as flint implements were flaked from their original cores. Direct comparison suggests that it was taken from a Proboscidean femur as large as that of *Elephas meridionalis*. In microscopic structure it agrees with Proboscidean bone. The two ends of the implement are shaped entirely by cutting, and bear no marks of grinding or rubbing. Most of the cut facettes are small, and many of them suggest that they were made by some primitive tool, presumably a flint. The rounded end seems to have been trimmed for comfortable handling. The thick pointed (or, rather, keeled) end does not show any signs of battering or scratching by use. Just above the pointed end one lateral edge of the bone is marked by a large smooth groove running across from the inner to the outer face of the bone. It seems to have been originally a perforation from which the outer wall has been accidentally broken away. Within it on the inner face is the beginning of a second similar perforation, as if an attempt had been made to repair the damage. The authors conclude that the implement is unique, and are unable to explain its specific use.

CORRESPONDENCE.

PRE-PALÆOLITHIC FLINT IMPLEMENTS.

Sir,—Mr. Hazzledine Warren and I evidently differ very widely on the question of man's antiquity. He expresses the opinion that the more our knowledge grows of the various ways in which a flint fractures, the less faith will archæologists have in the human origin of pre-Palæolithic flints; while I believe with equal steadfastness that the very reverse will be the case. Now, I am sure Mr. Warren is an earnest seeker after truth, and I hope I am also. Yet we disagree absolutely as to the correct interpretation of the evidence bearing upon this matter which has been collected, and it seems to me that it would be as well to attempt to put our respective opinions to a somewhat stringent test, and to ascertain, in fact, which of us knows most about flint fracture. Such a test will naturally remove this controversy from the realm of theoretical discussion to that of practical demonstration; but it is necessary to do this if any real advance is to be made in our knowledge of the subject, and I therefore submit the following proposals to Mr. Warren, which I hope he will seriously consider, and make known through the medium of your journal whether he accepts them or not. I take it Mr. Warren believes that the edge-trimmed flints, found chiefly in the Plateau Drift of Kent and usually described as 'eoliths', have been produced by some form of pressure. I, on the other hand, regard these specimens as having been flaked by blows, and I also believe that it is possible to differentiate between pressure and percussion flaking. I therefore propose that Mr. Warren selects forty flint pebbles, and that he flakes twenty of them by means of a hammer-stone of some sort into the usual hollow-scraper type of 'eolith', and subjects the remaining twenty to any form of pressure he likes which will also produce similar forms. Having done this, I would suggest he puts distinguishing and faithful marks upon each, by means of which he will know which have been flaked by pressure and which by blows, and that these specimens be then submitted to my examination at a meeting of some scientific body such as the Geological Society. If this is done, and if a good light is provided, I will then and there examine the forty flints and state which I consider have been flaked by pressure and which by blows, and further, if I do not judge 75 per cent of them correctly, I will then and there admit that my claim to be able to differentiate between the two forms of fracture is not substantiated.

It will be noticed I refer only to the simple edge-trimmed tabular flints first discovered by Mr. Benjamin Harrison, of Kent, and make no mention of the much more elaborately flaked specimens which have been found beneath the Red Crag of Suffolk. These form an entirely different subject of inquiry, and can be dealt with when the easier question of the 'eoliths' is settled. But if it turns out that I am vanquished in the contest I suggest, my views regarding the 'humanity' of the sub-Crag flints will naturally lose prestige, while if I should happen to be the victor it will show I am in possession of certain knowledge which enables me to say with a high degree of certainty whether a flint has been fractured by blows or by pressure, and that in consequence these views have received definite and solid support. I hope Mr. Warren will agree to accept these proposals, and that the result of my examination of the flints to be fractured shall appear in the pages of this journal.

J. Reid Moir.

CONCERNING LATERITE IN GUIANA.

Sir,—In 1911 I contributed an article to this Magazine entitled "What is Laterite?" which arose from a discussion in these pages, initiated by a review of Professor J. B. Harrison's work, *The Geology of the Goldfields of British Guiana* (1908). In this article I put forward a tentative system of classification of lateritic products, by which I proposed to test the use of the word *laterite* by certain authors. Amongst the work criticized was a paper by Professor Harrison entitled "The Residual Earths of British Guiana commonly termed 'Laterite'", in the Geol. Mag., 1910, pp. 439–52, 488–95, 553–62, and also that of Du Bois entitled "Beitrag zur Kenntniss der Surinamischen Laterite", published in *Tschermak's Mittheilungen*, 1903. I drew the conclusion (loc. cit., pp. 563–4), judging from the work of Harrison and Du Bois, that the term has been too widely used in the Guianas.

Last year I received from Professor Harrison a letter to which, owing to the distractions of furlough and travel, I have not been able, hitherto, to give the careful consideration it deserves. From Professor Harrison's letter it appears that my conclusion given above is too sweeping, and therefore in justice to Professor Harrison I am making this communication.

I cannot do better than quote a section of this letter:—

"With reference to the various points in my published papers noticed by you I may mention that I had not an opportunity of correcting the proofs, and hence there are in the papers some wordings which would have been amended if I had had such an opportunity; the copies I send you have been so corrected. Among them is the heading to Table I, on p. 441.[1] The object of that table is to illustrate the somewhat diverse nature of *sedentary* soils covering areas of aluminous laterite. This is clearly seen by reference to the last sentence of p. 440. Unfortunately, in copying the analyses, the word 'Ironstone' over the word 'gravel' in the fourth column of the table was omitted.

"During 1897–1902 I analysed several specimens of 'ironstone gravels' and found them to contain from 80 to as much as 95 per cent of iron and aluminum hydrates, principally the former. These bring up the lateritic constituents of some of these soils very materially, for instance:—

	$Fe_2O_3 + Al_2O_3$
Hiamaraka Hill soil	72 per cent
Arakaka	56 ,,
Konawaruk Road, 12 miles	33 ,,
,, ,, 14½ ,,	55 ,,
Woopu	72 ,,
Issorora	65 ,,
Malali	62 ,,

[1] Which Professor Harrison corrects from "Analyses of Laterite Soils" to "Analyses of Soils on Laterite".

But there are others resting directly on aluminous laterite or even bauxite that are practically, if not entirely, free from lateritic constituents; prominent among these are the soils at Akyma and at Christianburg, both of which are sedentary soils resting on beds of bauxite."

This correction invalidates my criticism on p. 562 (loc. cit.) to a large extent, and many of the products which I suggested should only be termed *clay*, *soil*, or *sand*, with or without the adjective 'lateritic', are obviously *argillaceous* and *siliceous laterites*.

Later in his letter Professor Harrison writes:—

"The specimens I described in the paper were all collected from low altitudes—below 500 feet—whilst many of them were from altitudes 20 to 180 feet only above sea-level. There are, however, as shown by C. B. Brown, during his geological survey of the colony, vast areas of the higher lands of British Guiana, 2,000 to 5,000 feet in altitude, covered with layers of concretionary ironstone gravels of lateritic origin.

"Recently an extended survey for railway purposes has shown that a vast area of British Guiana in altitude from 500 to 1,500 feet is covered by a ferruginous laterite which in composition corresponds to your definition of 'Typical Laterite', but which we have always termed 'ironstone'. It justifies from your point of view van Capelle's description of another part of Guiana as 'le pays de la latérite par excellence'."

In view of these remarks of Professor Harrison, it cannot be doubted that there are in the Guianas wide spreads of laterite. One feature in which the laterites of Guiana tend to differ markedly from those of India is the frequent presence of *secondary quartz*, which has been observed both macroscopically and microscopically by Professor Harrison in lateritic products derived from basic rocks originally containing little or no free quartz. This secondary silica is of such importance in places that it has segregated into quartz veins and reefs, which are sometimes auriferous (see pp. 446, 447, 489 of Harrison's paper). Many other authors, quoted on p. 490 of Professor Harrison's paper, have described auriferous quartz of secondary origin in the Guianas, e.g. Du Bois (loc. cit., pp. 21, 22), so that it seems impossible to doubt that frequently in the Guianas the process of lateritization has not been pushed to a finish owing to the non-removal of at least a portion of the silica of the original rocks. This may be due to the fact that, according to Harrison (loc. cit., p. 560), "in the dense forests of the Guianas there may be said to be a perpetual wet season, as under the shade of the trees, even during periods of comparative drought, the land is invariably wet and more or less soaked with water containing organic acids in solution." This last passage suggests that the ground-water level is very close to the surface, thereby rendering difficult the thorough drainage of the decomposing rocks. If this be so, then it seems as if the process of lateritization requires for its *completion* some condition, such as *the alternation of wet and dry seasons* so characteristic of many tropical lands, that will facilitate the periodical drainage from the soil of its contained solutions.

It would be interesting to learn whether there are in British Guiana any masses of laterite entirely free from secondary quartz, and, if so, whether such occurrences can be correlated with and explained by local topographical and climatic conditions.

L. Leigh Fermor.

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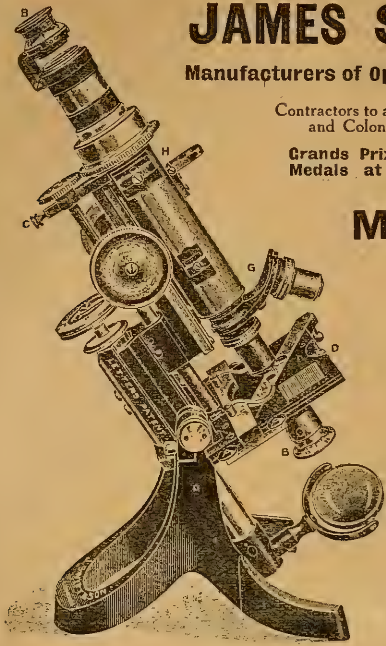

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. II.—FEBRUARY, 1915.

ORIGINAL ARTICLES.

I.—Studies in Edrioasteroidea. VI. *Pyrgocystis* n.g.

By F. A. Bather, M.A., D.Sc., F.R.S.

(Concluded from the January Number, p. 12.)

C. *Pyrgocystis anstícei* n.sp. and others. (Plate III, Figs. 3–15.)

Previous History.—In 1892 Professor Carl W. S. Aurivillius published his well-known paper "Ueber einige ober-silurische Cirripeden aus Gotland" (Bihang Svenska Vet.-Akad. Handl. Bd 18, Afd. IV, No. 3). Besides the remarkable specimen from the Ludlovian *Pterygotus* bed of Wisby, to which he gave the name *Pollicipes signatus*, and a supposed fragment of a scutum, which he called *P. validus*, Professor Aurivillius described a number of "kurze, mehr oder weniger cylindrische, mit Schuppen bedeckte Bildungen", which he regarded as the peduncles of a cirripede and referred provisionally, in the absence of any trace of a capitulum, to *Scalpellum*. Though all the specimens (except possibly of *S. cylindricum*) came from a single stratum, bed *c* of Lindström, probably contemporaneous with our Wenlock Shale, and though the majority were found in a single locality, Djupvik in Eksta, still Professor Aurivillius considered that he could with certainty distinguish the following seven species:—

S. sulcatum,	p. 13, fig. 11,	Bed *c*,	Djupvik,	abundant.
S. varium,	p. 15, figs. 12–14,	,,	,,	1 specimen.
S. granulatum,	p. 16, figs. 20–22,	,,	,,	3 ,,
S. ,, ?	p. 17,	,,	Wisby,	some ,,
S. strobiloides,	p. 17, figs. 17–19,	,,	Mulde,	1 ,,
S. procerum,	p. 18, fig. 15,	,,	Wisby,	? ,,
S. ,,		,,	Djupvik,	? ,,
S. fragile,	p. 19, fig. 10,	,,	Djupvik, Wisby,	3 ,,
S. cylindricum,	p. 18, fig. 16,	(horizon not stated),	Wisby,	1 ,, .

In 1906 Colonel [now] Sir J. Arthur Anstice, K.C.B., a son of the Mr. John Anstice of Madeley whose collection was mentioned by Murchison and Prestwich, presented to the British Museum various fossils from the Coalbrookdale district; and among them were 14 specimens of the same character as those described by Aurivillius, and like them coming from the Wenlock Shale. Consequently they were at first placed provisionally among the Cirripedia. When, however, Professor Moberg's recent memoir (1914) led us to look through our Palæozoic cirripedes, Mr. T. H. Withers directed my attention to these fossils. Immediately close examination under the lens revealed at the broken edges of the plates the clean crystalline cleavage distinctive of calcite and of echinoderm stereom, but not found in fossil remains of Arthropoda. Their echinoderm nature once recognised, it is further clear that all these fossils represent the stems or turrets of species resembling those from Minnesota and Girvan so far as that portion of the anatomy is concerned, and probably resembling them in the structure of the oral face. It is interesting to note that among the Gotland fossils referred by Aurivillius to *Scalpellum sulcatum*, is one which Hisinger had previously figured as "Columnæ Crinoidis fragmentum" (1841, *Lethæa Suecica*, Supplementi Secundi Continuatio, pl. xli, fig. 6). This reference by Hisinger, which, bearing in mind the former extended connotation of the name Crinoidea, now proves perfectly correct, seems to have aroused no sūspicions in the mind of Aurivillius. On the contrary, he was quite certain that these fossils represented the stems of some genus of Lepadidæ, and, despite the great extension of geological range involved and the absence of congeners earlier than Cretaceous, he scarcely hesitated to refer them to the characteristically recent genus *Scalpellum*.

Students of early Palæozoic fossils know how often it has proved difficult to decide whether isolated plates, or associated fragments, or even whole skeletons, belonged to the Echinoderma or to the Arthropoda; but the criterion of stereom-structure, when it can be applied, ought to prove decisive. Apart from that, in the present instance, Aurivillius himself notes that in the peduncles of Recent Cirripedia the scales are embedded in a thick [uncalcified] chitin, or are only fastened by the base. In other words, the peduncle-valves of the cirripedes are never so closely set or so deeply imbricate as are the plates in these Silurian fossils; and the consequence of this is that up to the present, as Mr. Withers assures me, only two specimens are known in which a scalpelliform peduncle has been preserved in the fossil state with its valves in place,[1] and not a single one has been found apart from its capitulum. What a contrast is provided by the fossils before us, of which over a score have been picked up on a single beach in Gotland and fourteen in one Shropshire lane!

But apart from these fairly obvious considerations, which would have made an ordinary palæontologist hesitate, the general shape of the individual plates might well have raised a doubt in the mind of so high an authority on the recent Crustacea as Professor Aurivillius. The peduncular valves of cirripedes always show growth-lines over the whole outer surface, and definite facets where they abut or overlap; they are clear-cut structures, and in *Scalpellum* at any rate the earlier the species the more characteristic is the shape of the plate. But the plates of these Wenlockian fossils show at the most some minute irregular granules or rugæ, and have no distinct ridges or facets; they are quite unlike any cirripede plates of either Silurian or Recent times.

[1] *Scillælepas carinata* (Phil.), Miocene, Sicily: Seguenza, 1876, Atti Accad. Pontaniana, vol. x, pl. viii, fig. 14; and *Pollicipes concinnus* Morris, Oxford Clay, England: Darwin, 1851, Pal. Soc. Monogr. Foss. Lepadidæ, p. 50, pl. iii, fig. 1.

Material.—The fourteen specimens presented to the British Museum by Sir Arthur Anstice are registered E 16233 to E 16246, but may for convenience of reference be denoted by the letters *a* to *n*. They are all turrets in various degrees of preservation. Specimen *c* [E 16235] is taken as holotype.

Horizon and Locality.—All are from the Wenlock Shale of Jig House Bank, or, in the local vernacular, "Jiggers Bank." This, says Sir A. Anstice *in litt.*, "is a road that runs from Coalbrookdale up the right hand side of a steep dingle called Lloyd Brook dingle (the main road from Coalbrookdale to Wellington runs up this hill) . . . the road runs up the side of a steep bank, and there is a place called the Loam or Lum hole in the lower part of the dingle."

Detailed Description.—These fossils closely resemble the "*Scalpellum sulcatum*" of Aurivillius, with whose description the following may be compared.

The Turret is slightly curved and increases gradually in diameter from below upwards, frequently expanding rather suddenly at its adoral end, where the plates appear more closely packed.

The plates are arranged in eight columns, which may (as in *c*, Pl. III, Fig. 4) be quite distinct with grooves between, but which may be partly merged so that it is hard to say whether the number is 7 or 8 (e.g. *a*, *b*, *f*, *k*; Pl. III, Fig. 3), or may be clearly not more than 7 (e.g. *d*, *e*; Pl. III, Fig. 5). The vertical seriation is most plain in the middle half of the turret; towards the adoral end there is nearly always an irregularity connected with the expansion of the turret, which is usually more on one side and affects the packing of the plates; towards the lower end, as the turret contracts, the columns inosculate and become reduced in number, so that there may be only 4 or 5 at the base, increasing to 7 or 8 above (e.g. *l*, *m*; Pl. III, Figs. 6, 10). When the irregularity of the upper expansion has come in before the increasing plates of the lower end have taken their positions in definite columns, then the arrangement appears quite irregular (e.g. *j*). In those regions of the turret, or in those individuals, in which the complete arrangement in eight distinct columns has not been attained, the inosculation of the plates frequently appears on the surface as a column of smaller plates between two columns of larger ones; one result is the absence of a groove between the columns and a more even rounding of the surface, as described by Aurivillius for his *S. varium* and *S. strobiloides*.

The shape of the visible portion of each plate varies with the extent to which it is exposed, and with the greater or less distinctness of the columns. The shape of the whole plate is given in Pl. III, Figs. 14, 15; and the only variation of this seems to be in the greater or less relative width, producing a more obtuse or more acute angle. The sides of the upper half of the plate form a somewhat parabolic curve, the whole of which may be exposed; but however little be exposed it can never be likened to the segment of a circle. In the lower half of the plate the sides become more straight and vertical, or even converge slightly. Of course it is only at the distal end of the turret that the plates are ever fully exposed, and it is probable that the relative height is greater there. The measurements of such plates in millimetres are :—

	a	*c*	*e*	*j*
Height	2·9	1·8	2·75	2·7
Greatest width . . .	2·0	1·6	1·8	1·6
Depth of portion exposed .	·6	·4 or less	·5	·2 in column, 1·5 when alternating.

Thus the ratio of width to height varies from ·88 to ·59 in different individuals, when plates of the same character are compared.

The number of plates in a column is 21 in *a* with a total height of 8·2 mm., 18 in *c* with a total height of 7 mm., about 16 in *e* where the portion preserved has a height of 5·6 mm., about 23 in *g*, with an approximate height of 8 mm. These numbers seem to imply that the plates are closer than in *S. sulcatum*, according to the measurement given by Aurivillius, who says 20 plates in 10 mm. But that measurement does not seem to take into account the more crowded plates at the two ends. His figure 11 suggests that there were in that specimen 27 plates in a height of about 10 mm. Probably there was no difference in this respect between individuals of the two species with clearly marked columns.

The amount of overlap is gauged by the proportion of depth of a plate exposed, and this in vertical series is somewhere about one-fifth. Aurivillius says of *S. sulcatum* "eine Schuppe nur die Hälfte oder oft nur $\frac{1}{3}$ der nächststehenden freilässt", but later on he gives the actual measurements for the middle region of the turret as ·5 in a length of 2·5 mm., i.e. one-fifth.

As regards the mutual relations of the plates in a tier, Aurivillius says: "Was die Anordnung in die Quere betrifft, stehen die Schuppen jeder zweiten Reihe auf derselben Höhe." If we letter the plates in a tier *a* to *h*, reading from right to left, then this sentence conveys the impression that the arrangement is as follows—

h		*f*		*d*		*b*	
	g		*e*		*c*		*a*

It will be observed that a repetition of this order in successive tiers would produce a line of the same letters ascending in spiral from right to left, *a* overlapping *b*, *b* overlapping *c*, and so on—

h		*f*		*d*		*b*	
	g		*e*		*c*		*a*
h		*f*		*d*		*b*	
	g		*e*		*c*		*a*
h		*f*		*d*		*b*	
	g		*e*		*c*		*a*
h		*f*		*d*		*b*	
	g		*e*		*c*		*a*

and a similar line descending from right to left, *b* overlapping *a*, and so on. This spiral arrangement is not conspicuous when the plates overlap closely, as in Aurivillius' fig. 11, and in those of our specimens that have clear vertical columns; but it is very plain when the overlap is less, though the alternation remains regular, as in Aurivillius' figs. 12, 15, 16, assigned by him to other species.

The slope of the plates towards the axis of the turret appears to be much as represented in Aurivillius' fig. 13, i.e. nearer the vertical below, and nearer the horizontal above.

In *c* the lumen at the lower end has diameters of 1·4 and 1·1 mm. The diameter of the turret at the top of the first tier of plates is 3·2 and 2·9 mm. (Pl. III, Fig. 8). This is the only specimen that shows a definite lumen at the distal end. In other cases the lumen is filled with plates (Pl. III, Fig. 7), or with plates and secondary calcite (Pl. III, Fig. 9), or it may be quite covered over with plates in a more horizontal position. Grinding down *n* at the distal end displays a section with diameters about 1·3 mm. and 2·9 mm. Aurivillius gives for *S. sulcatum* a lumen-diameter of barely 1 mm. and a turret-diameter [? same specimen and level] 3·5 mm. This indicates a relatively smaller lumen, but he says that the width increases towards the imagined capitulum. The section which he figures of *S. varium* (fig. 13) represents a different set of proportions; here the lumen does not increase upwards, but the contrary if anything, and at its lower end it is more than half the diameter of the turret, at its upper end a little less than one-third. In *S. strobiloides* the diameter of the lumen is said to be three times that of the wall; i.e. three-fifths the diameter of the turret. It is very doubtful whether the width of the lumen increased upwards in our Shropshire species; in the fossils at any rate it is filled with the more horizontally disposed and crowded plates, whose position cannot entirely be due to post-mortem shifting (Pl. III, Figs. 11, 12, 13).

The plates, when well preserved, are covered externally with fine anastomosing rugæ, showing a tendency to radiate towards the curved margins. Since these are developed equally on the exposed and unexposed portions of the plate, they must be regarded not as superficial ornament, but as an expression of stereom structure.

The plates are frequently broken on their free margins, so that either the tops are truncate or great pieces are, as it were, bitten out leaving jagged points conforming to the lines of crystalline cleavage (Pl. III, Fig. 3). This frequently gives the turret sides quite a peculiar appearance, as though they belonged to an entirely distinct species. The tops of the plates seem to be broken in the specimen of *S. strobiloides* shown in Aurivillius' fig. 17, which reminds one of the appearances in the Minnesota fossils.

There is no trace of any spines or spinules. But in *b* at the distal end, which is rounded, the ordinary large turret-plates seem to be covered by a number of very small plates the meaning of which is obscure.

Not a single specimen shows any trace of the oral face.

Measurements in millimetres are as follows:—

	a	*c*	*g*	*h*
Greatest length of turret	8·2	7	8·1	5·3
Diameter at adoral end .	4·0 × 4·4	4·9	5·1 × 5·7	2·2 × 3·5
Diameter at distal end .	ca. 3·0	3·2	ca. 3·6	1·5 × 2·8

Distinctions between the Wenlockian Species.—In spite of the variation as regards number and distinctness of vertical columns, there are good reasons for regarding all the Coalbrookdale specimens as belonging to a single species. First, the variations themselves merge into one another, and do so in such a way as to suggest that they represent stages of development, from fewer to more columns, and from alternation to seriation of plates. Secondly, there is little or no variation in the shape of the individual plates and in the nature of their ornament; and it is by characters such as these, little influenced by the cruder forces of the environment, that genetic differences are usually distinguished.

If now we apply the conclusions drawn from these Shropshire fossils to their contemporaries from Gotland, we find that the differences relied on by Aurivillius to distinguish his species are for the most part those which appear to us as simple growth variations. So far as figures and descriptions allow one to judge, there seems no good reason why *S. sulcatum*, *S. varium*, and *S. fragile* should not all belong to a single species, for which the name *Pyrgocystis sulcata* would most naturally be adopted. *S. strobiloides*, represented only by the sole fragment found at Mulde, is probably no more than a slight variation, owing much of its different appearance to difference of preservation. *S. granulatum* seems to be distinguished by the nature of its ornament, but this again may only be due to better preservation; we have seen in *P. ansticei* that no weight can be attached to the difference in the direction of the plates at the distal end. Of the two long, cylindrical forms, *S. cylindricum*, known only from a single specimen, has plates of more pointed shape, and, since its horizon is possibly different, it may perhaps be left in its independence. The other, *S. procerum*, may also be distinct, but is more likely to consist merely of elongate individuals of *S. sulcatum*. It must be borne in mind that none of these specimens is really complete.

So much for the supposed differences between these Gotland forms. On the other hand, all, with the sole exception of the unique *S. cylindricum*, have plates of the same shape, namely, with the visible portion forming, in the words of Aurivillius, a segment of a circle. This fact, while confirming the view that they represent but a single species, sufficiently distinguishes them from the Shropshire specimens, in which the outline is consistently parabolic.

In the absence of any evidence to the contrary, such as might conceivably have been furnished by the oral face, these Wenlockian species must be referred to the genus *Pyrgocystis*.

The Relationships of Pyrgocystis.—It is clear that *Pyrgocystis* is an Edrioasteroid, but it is not clear whether it is to be referred to the Agelacrinidæ or the Edrioasteridæ. We need not consider either the Cyathocystidæ or the Steganoblastidæ in this connection.

According to the definitions given by me in 1899 and 1900 ("Treatise on Zoology," pp. 207–208), it would go more readily with the Agelacrinidæ; but in those definitions the differences in the subvective skeleton were not sufficiently taken into account.

In Studies I, II, IV, and V, the subvective skeleton of four Edrioasterid genera has been described in detail, and shown to consist of floor-plates and cover-plates, both disposed in alternating series, with pores between the floor-plates.

The evidence adduced by C. F. Roemer (1851), F. B. Meek (1873), Miller & Faber (1892), O. Jaekel (1899), J. M. Clarke (1901), and W. K. Spencer (1904) proves that in *Agelacrinus* (sensu lato) and *Hemicystis* among Agelacrinidæ, the subvective skeleton likewise consists of floor-plates and cover-plates, but that the floor-plates form a single series stretching right across the groove, and show no trace of pores. There is also a difference in the cover-plates, for normally in these two genera, as also in *Cystaster* and *Streptaster*, they are boot-shaped, with the sole of the boot adoral (= proximal) and the toe of the boot admedian, and in consequence of this shape they cannot close in the groove so completely as do the symmetrical cover-plates of the Edrioasteridæ. In some species of *Agelacrinus*, as shown in J. Hall's well-known figure of *A. cincinnatiensis* (1871), there are small additional cover-plates along the median line, much as may occur exceptionally in *Edrioaster* (Study IV, text-fig. 2). These additional plates, however, involve no departure from the essential plan of either group.

These two plans do not, I believe, exhaust the actual constructions employed in the Edrioasteroidea. Setting aside *Cyathocystis* and *Stromatocystis*, in which the structure is still not fully known, we may note *Lebetodiscus* (Study III), in which the cover-plates appear to be minute and to lie over the sutures between the floor-plates. The specimen figured by Jaekel (1899, *Stammesges. d. Pelmatoz.*, pl. ii, fig. 2) as *Agelacrinus Dicksoni* Billings, presents notches along the sides of its supposed cover-plates, and in other specimens I have observed these notches to be very distinct and regular: so that in such forms, it has seemed to me, there may have been minute cover-plates resting in the notches, and the larger visible plates may really be floor-plates.

The specimens of *Pyrgocystis*, so far as one can judge from the obscure evidence, do not display either cover-plates or floor-plates of the typical Edrioasterid or Agelacrinid plan. It is, however, conceivable that the plates observed correspond to the notched plates of the third plan of structure. Appearances that may possibly represent notches have been mentioned in the description of *P. grayæ*, and indications that the plates may perhaps not be cover-plates have been given in the description of *P. sardesoni*.

Those species which seem to me to have this supposed third plan of subvective structure, appear in all other points more closely allied to the Agelacrinidæ than to the Edrioasteridæ. In those same points it is with the Agelacrinidæ that *Pyrgocystis* also agrees. Therefore this genus may for the present be left in that Family. Although *Steganoblastus* is the genus of Edrioasteroidea that has the most pronounced stem, and that manifests in its thecal structure the most pronounced reaction to such a mode of fixation, still it differs greatly from *Pyrgocystis* in the crinoid-like nature of that stem, in the solidity of the theca, and in the Edrioasterid character of the subvective skeleton. *Cyathocystis* again, especially in its more elongate individuals, presents a subvective system of straight grooves mounted on a turret of much the same proportions as in *P. sardesoni*. But the turret in *Cyathocystis* is a solid tube, and the structure of the whole oral face is totally different.

Among the Agelacrinidæ are some genera that approach *Pyrgocystis*. *Cystaster granulatus* as defined by J. Hall (October, 1871), from which Jaekel has attempted to separate some specimens as *Thecocystis sacculus* (1899), has straight rays surmounting an elevated sac-like body composed of minute plates or granules. In *Hemicystis* also the rays are straight, and Hall (October, 1871) specially mentions that *H. parasitica* and *H. stellata* have "the sides more abruptly elevated than the ordinary forms of *Agelacrinus*". The theca in *Hemicystis* is composed of minute squamiform plates. *Agelacrinus pileus* is said by Hall to have a "globular bell-shaped" theca when well preserved, and he figures a specimen in which many of the interradial plates "have a rounded node near the centre", possibly a spiniferous tubercle. In this species, as in all "*Agelacrinus*", the rays are curved.

The occurrence of spines in Pelmatozoa was probably more common than is generally supposed, but their preservation is certainly rare. Had specimen *a* of *P. sardesoni* not been found, nobody would have supposed that any species of *Pyrgocystis* bore spines; and the fact that they are not known in the other species is no proof that they were not present. No stress should be laid on the appearance of vertical rods on the cup-plates of *P. grayæ*, since they may be merely strengthening ridges. Meek (1873, Rep. Geol. Surv. Ohio, vol. i, pt. 2, p. 56) mentions ridges on the inner surface of marginal plates in an *Agelacrinus cincinnatiensis* (?).

Bionomics of Pyrgocystis.—The three formations from which specimens of this genus are known are of different lithological character.

P. sardesoni is found in a thin-bedded limestone, intercalated in soft green shales, and composed of numerous small fossils and fragments, but mainly of bryozoan skeletons, especially of branching bifoliate forms. This seems to suggest pure, relatively shallow water, crowded with animal life. The skeletons afforded a firm base of attachment for the Edrioasteroid's turret, which was under no necessity to be lofty since there was abundance of food and of aërating currents. There is no indication that the turret was fixed in other than a vertical position. The spines might conceivably be ascribed to some innate acanthogenous agency, or (less mystically) to an excess of lime in the water; but, whatever the contributory causes, we may suppose that the longer spines on the oral face were useful as a defence against worms and other predatory foes, while the spinules on the turret may have protected the soft stroma from parasitic organisms.

P. grayæ is preserved in a sandstone from which, as generally found, the calcareous constituents have been leached. This also was a shallow-water formation, but not so rich in life as the Stictoporella bed, and especially poor in sedentary organisms. No firm base was afforded for the turret, which therefore seems to have tapered off to a pointed end thrust in the soft sand, while upwards it grew out of the reach of a bombardment by sand-grains (cf. "Caradocian Cystidea from Girvan", § 558). By the domed elevation of the oral face, the accumulation of sand-grains over the subvective system was prevented. The water was not so rich in lime, and parasitic enemies were not so numerous, wherefore it is probable that the reason why spines have not been preserved is because they never were developed in this species.

The Wenlock Shale of Shropshire, like the contemporaneous Bed *c* in Gotland, is a very fine-grained shale, apparently deposited in calm waters, in which lived a fairly numerous but rather dwarfed fauna, rich in ostracods and in small brachiopods and trilobites. There was no good fixation for the turrets, which seem therefore to have been rounded off at the distal end, and presumably stuck in the ooze, but may possibly have been attached to seaweeds. Frequently, it seems, they did not stand upright, and therefore grew in a slight curve. As a rule, relative want of lime made their plates thin and of a loose texture as now manifested in their dark colour. This also did not encourage the production of spines, which probably were absent. The differences between the various Wenlockian species do not seem to be of much physiological importance.

The results of the present Study may now be summarised in the following *Diagnoses.*

Pyrgocystis[1] n.g.

An Agelacrinid with a subvective system of five broad straight rays mounted on a subcylindrical turret of adorally imbricate thin wide plates, which are not markedly different from those of the interradial areas of the oral face.

Range.—Lower Ordovician to Middle Silurian.

Genotype.—*P. sardesoni.*

P. sardesoni n.sp.

A *Pyrgocystis* with diameter of turret equal all the way up, and about two-thirds its height, which is about 14 mm.; turret-plates in about 48 tiers of 11 plates in each, irregularly alternating and nowhere forming the complete 22 columns; each plate is from two to three times as wide as high, and is shaped like a segment of a flat ring. Not more than one-third of each plate is exposed. At the distal end of the turret the plates are almost horizontal; towards the proximal end they gradually approach the vertical, and finally merge into the interradial plates of the oral face, which is approximately horizontal. Spines are borne by all plates, those on the turret-plates being minute and not readily preserved.

Holotype.—Brit. Mus., Geol. Dept., E 16232.

[1] πύργος, a tower.

Horizon.—Stictoporella bed, Decorah shales, Lower Ordovician.
Locality.—St. Paul, Minnesota, U.S.A.

P. GRAYAE n.sp.

A *Pyrgocystis* with turret markedly tapering distalwards, its diameter in the proximal region about one-fifth its total height, which is about 20 mm.; turret-plates in about 80 tiers of about 5 plates in each, which in the proximal region alternate regularly so as to form about 10 columns; each plate appears to be probably wider than high, and to have an outer margin shaped like a flattened arc of a circle; the amount exposed is uncertain. The turret-plates seem to be laid at a steep pitch throughout; at the proximal end they form a distinct, almost vertical-walled, kind of cup, from which springs the high-domed oral face. Spines not observed.

Holotype.—Collection of Mrs. Robert Gray, Edinburgh, K 8.
Horizon.—Starfish bed, Drummuck series, Upper Ordovician.
Locality.—Thraive Glen, Girvan, Ayrshire, Scotland.

P. ANSTICEI n.sp.

A *Pyrgocystis* with turret slightly tapering distalwards, its diameter in the proximal region about one-half to two-thirds its total height, which is about 8 mm.; turret-plates in about 50 (or fewer) tiers of not more than 4 plates in each, which in the middle region alternate regularly, often forming 8 distinct columns separated by grooves; the width of each plate is from six-tenths to nine-tenths of its height; amount exposed about one-fifth, its margin a parabolic curve. The slope of the turret-plates in the fossils is nearer the vertical at the distal end, nearer the horizontal at the proximal end. Oral face and spines not observed.

Holotype.—Brit. Mus., Geol. Dept., E 16235.
Horizon.—Wenlock Shale, Middle Silurian.
Locality.—Jig House Bank near Coalbrookdale, Shropshire, England.

P. SULCATA Aurivillius sp.

Scalpellum sulcatum Auriv. 1892, p. 13.
Scalpellum varium Auriv. 1892, p. 15.
Scalpellum fragile Auriv. 1892, p. 19.
? *Scalpellum strobiloides* Auriv. 1892, p. 17.
? *Scalpellum granulatum* Auriv. 1892, p. 16.

A *Pyrgocystis* with turret slightly tapering distalwards, its diameter in the proximal region about half (or a little less) of its total height, which is about 11 mm.; turret-plates in about 50 (or fewer) tiers of not more than 4 plates in each, which alternate regularly, often forming 8 distinct columns, separated by grooves; the width of each plate appears [from Aurivillius' drawings; no measurements are given] to be greater than its height; amount exposed about one-fifth. its margin an arc of a circle. The slope of the turret-plates in the fossils is nearer the vertical towards the distal end, nearer the horizontal at the proximal end, but they may be compressed and flattened at the extreme distal end. Oral face and spines not observed.

Holotype.—The original of Aurivillius' plate-fig. 11 is hereby selected. It is in the Riksmuseum, Stockholm. The holotype of *Scalpellum varium* is the unique original of Aurivillius' plate-fig. 12. The original of Aurivillius' plate-fig. 10 is hereby selected as holotype of *S. fragile*; it is not the specimen measured. The holotype of *S. strobiloides* is the unique original of Aurivillius' plate-fig. 17. The specimen measured by Aurivillius (p. 16) is hereby selected as holotype of *S. granulatum*; the figures may or may not be taken from this. All these specimens also are in the Riksmuseum, Stockholm.

Horizon.—Bed *c* (= Wenlock Shale), Middle Silurian.

Locality.—Djupvik in Eksta, also at Mulde and near Wisby, Gotland, Sweden.

P. PROCERA Aurivillius sp.

Scalpellum procerum Auriv. 1892, p. 18.

A *Pyrgocystis* with turret almost cylindrical, its diameter in the proximal region about one-third of its total height, which is not less than 10 mm.; turret-plates in at least 25 tiers of 4 plates in each, which alternate regularly, forming 8 columns separated by faint grooves; the width of each plate appears to be greater than its height; amount exposed fully one-half, its margin an arc of a circle; each plate is slightly bent on its vertical axis. The slope of the turret-plates approaches the vertical in all the portion preserved. Oral face and spines not observed.

Holotype.—The original of Aurivillius' plate-fig. 15 is hereby selected; it appears to be the specimen measured (p. 18). It is in the Riksmuseum, Stockholm.

Horizon.—Bed *c* (= Wenlock Shale), Middle Silurian.

Locality.—Aurivillius gives *a*) near Wisby, *b*) Djupvik in Eksta. I do not know from which of these the holotype came.

P. CYLINDRICA Aurivillius sp.

Scalpellum cylindricum Auriv. 1892, p. 18.

A *Pyrgocystis* with turret almost cylindrical, its diameter not more than one-third of its total height, which is not less than 9 mm.; turret-plates in at least 12 tiers of 4 plates in each, which alternate regularly, forming 8 columns, which are not separated but closely inosculate; the width of each plate is very little (if at all) greater than its height; amount exposed about two-thirds, its margin a pointed arch. The slope of the turret-plates approaches the vertical in all the portion preserved. Oral face and spines not observed.

Holotype.—The unique original of Aurivillius' plate-fig. 16, in the Riksmuseum, Stockholm.

Horizon.—Silurian, precise bed unknown.

Locality.—Near Wisby, Gotland, Sweden.

EXPLANATION OF PLATE III.

Pyrgocystis grayae.

FIG. 1. The holotype seen in three-quarter view from above, so as to show the oral face.

,, 2. The holotype seen from the side.

Both these figures are photographs from a squeeze of the original. × 3 diam.

Pyrgocystis ansticei.

,, 3. Specimen *a*. Side view. Note the irregular shape of the plates, due to fracture.

,, 4. Specimen *c*. Holotype, side view. Note the regular plates arranged in columns.

,, 5. Specimen *e*. Side view. Note the slightly irregular columns, of which there are only 7.

,, 6. Specimen *l*. Side view. Note the small number of columns at the distal end, with new ones coming in above.

,, 7. Specimen *g*. View of distal end. Since the turret is much curved, its side is also visible, though out of focus. There is no trace of a lumen.

,, 8. Specimen *c*. Holotype, view of distal end. The turret is slightly curved. There is a small distinct lumen.

,, 9. Specimen *e*. View of distal end. The position of the lumen is filled with a solid mass of plates and secondary mineral matter.

,, 10. Specimen *m*. Side view. Note the irregularity of the columns near the tapering distal end.

,, 11. Specimen *a*. View of adoral end. Note the approach to horizontality of the plates, and how they stretch across the lumen.

,, 12. Specimen *c*. Holotype, view of adoral end, as in Fig. 11.

,, 13. Specimen *i*. View of adoral end. Traces of the lumen are seen filled with matrix.

All the preceding figures, 3–13, are from photographs, taken and worked up by the author. × 3 diam., the same scale as Aurivillius' figures.

,, 14. Specimen *c*. Holotype. A plate at the distal end. × 7·5 diam.

,, 15. Specimen *j*. A plate at the distal end. × 7·5 diam.

Unfortunately it has not proved possible to obtain for comparison similar drawings of the plates in the Swedish species.

II.—Radio-activity and the Earth's Thermal History.

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

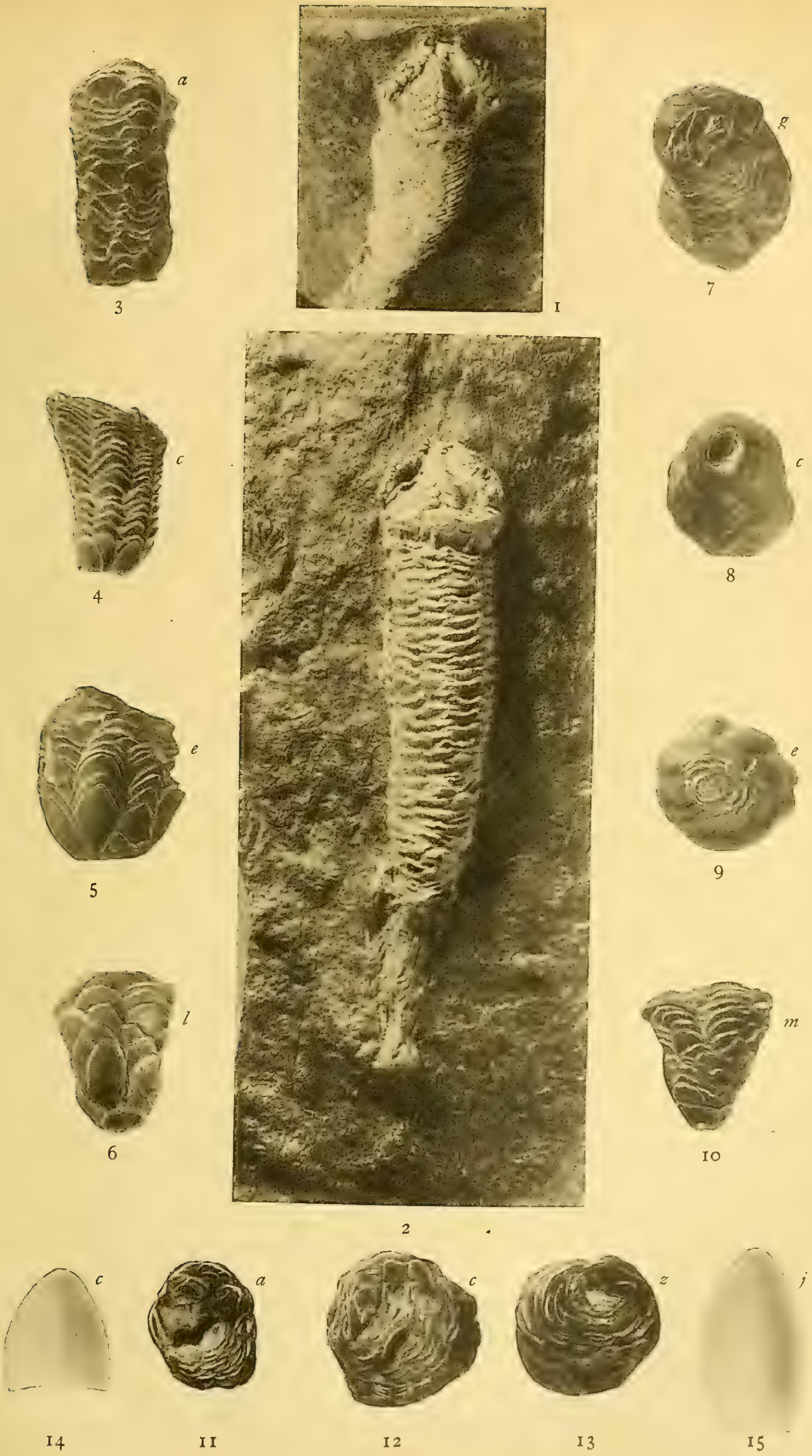
PART I.

The Concentration of the Radio-active Elements in the Earth's Crust.

1. Introduction.

TWO years ago, in discussing the thermal energy of the earth,[1] I suggested that while it had become impossible to deduce the earth's age from its thermal condition alone, Kelvin's problem might profitably be reversed by accepting the earth's age as a known factor, and deducing with its help the thermal history of the earth. This paper is a first attempt to attack the new problem then suggested. For geological purposes, one of the most fundamental aspects of the

[1] *The Age of the Earth*, p. 135, 1913.



London Stereoscopic Co., imp.

PYRGOCYSTIS GRAYAE, P. ANSTICEI.

problem is that relating to the depth within the earth's crust at which temperatures are attained such that, under suitable conditions of pressure, molten rock magmas may exist. The determination of the minimum depth of possible rock fusion is a first essential to any adequate theory of vulcanism, and indeed of igneous activity in general. It is not sufficient, however, to ascertain that depth for present conditions alone. Its variation during the earth's geological history must also be investigated; for if, as is generally believed, the earth is a cooling body, the depth must be slowly increasing, and in former periods it must necessarily have been nearer the surface than it is now. In the limiting conditions both of position and time, the depth of fusion may have been at, or so near as to be for all practical purposes at, the surface itself. That is to say, at the beginning of geological history the earth may have been in a molten condition at, or immediately below, the then existing surface.

The necessity of investigating this problem afresh arises from the discovery, within the last decade, of the widespread distribution of radio-active elements among the rocks of the earth's crust.[1] Although numerically the actual proportion of the radio-elements in the rocks is exceedingly small, yet owing to the fact that their disintegration is accompanied by a spontaneous generation of heat, it happens that their presence is fraught with a significance that cannot be over-emphasized. If each gram of the earth's substance were as rich in the radio-elements as are the rocks which have been examined, the earth's total output of heat from this source alone would, in any given period, be about 300 times as great as the amount actually lost by conduction to the surface and radiation into space.[2] If for 'gram' in the above statement, we substitute 'cubic centimetre', then the heat income would be more than fifty times the heat expenditure.

This astonishing result pulls us up sharply, for it is manifestly absurd to believe that our planet is becoming hotter at the appalling rate implied in these figures, or, indeed, that it is becoming hotter at all. There are two possible ways by which the dilemma may be avoided. The radio-active elements may be largely confined to the crustal rocks, leaving the main body of the interior free from the embarrassing results of their energetic decay; or, on the other hand, the disintegration to which the heat owes its origin may be inhibited under the conditions prevailing in the earth's interior. In the immediate problem before us, it matters little which of these views be accepted, for in each case the radio-active generation of heat is restricted to a superficial shell. It should, however, be pointed out that there is a strong consensus of experimental evidence pointing to an actual concentration of the radio-active elements in the earth's crust, whereas there is no evidence whatever that physical conditions can influence the rate of disintegration and heat production.[3] The experiments already made have reached temperatures up to 2500° C., and pressures

[1] Strutt, Proc. Roy. Soc., A, vol. lxxvii, p. 475, 1906; Holmes, *Science Progress*, No. 33, p. 15, 1914.

[2] Holmes, *Science Progress*, No. 33, p. 21, 1914.

[3] My *Science Progress* paper (No. 33, 1914) deals fully with this question.

up to 160 tons to the square inch,[1] which are quite sufficient for geological purposes, since they represent average conditions which cannot be generally reached at depths of less than 50 miles, or 80 kilometres, below the surface of the earth. To that depth, at least, the assumption of complete radio-active independence is thoroughly justified by direct experimental evidence. Since for thermal reasons the radio-active elements must be largely concentrated in an outer shell, it is of very little geological importance to decide the question of possible inhibition at depths greater than 50 miles.

2. Distribution of the Radio-active Elements.

As a result of a large number of experimental determinations of radium[2] in rocks and meteorites, first initiated by Strutt[3] and since continued by other workers,[4] it is now possible to state with confidence the salient features of the distribution of radium in rocks and meteorites of different types.

(1) Igneous rocks as a whole average more radium than sedimentary rocks.

(2) Metamorphic rocks agree in their averages with those of the igneous or sedimentary rocks from which they have been formed.

(3) The average for alkaline igneous rocks is higher than that for calc-alkaline rocks, and this important fact must be remembered in connexion with local exceptions to statement 5.

(4) The average for volcanic rocks is higher than that for plutonic rocks.[5]

(5) Acid igneous rocks average a higher content of radium than those of intermediate composition, and the latter, in turn, are richer than basic and ultra-basic rocks.

(6) The ultra-basic stony material of meteorites is poorer in radium than are terrestrial ultra-basic rocks.

(7) The metallic material of meteorites contains no radium, and in keeping with this significant fact terrestrial native iron is also free from radium.

Estimations of thorium have not been so numerous as those of radium, and most of the work has been done in the laboratories of

[1] Eve & Adams, *Nature*, p. 209, July, 1907.

[2] One part of radium in equilibrium with its parent uranium implies the presence of 3,000,000 parts of the latter element.

[3] Proc. Roy. Soc., A, vol. lxxvii, p. 472, 1906.

[4] See Joly, *Phil. Mag.*, vol. xxiv, p. 694, 1906; Holmes, loc. cit., p. 15, 1914, for references to literature.

[5] The unusually high radium content of recent Vesuvian lavas found by Joly is probably due to—

(1) Gravitational differentiation.

(2) Concentration by volatile fluxes.

(3) Association of radium, unaccompanied by its parent uranium, with potash minerals. It is well known that barium is commonly associated with magmas rich in potash, and it is therefore suggested that free radium may be similarly concentrated. In old lavas any such free radium would almost entirely have disintegrated, leaving to be measured only the radium which is directly related to the uranium present in the rock.

Professor Joly in Dublin, and Professor Mache in Vienna.[1] The results so far available serve to show that in the case of rocks the above statements serve equally well for thorium as for radium. Independently, this parallelism of distribution and mode of occurrence would be forcibly indicated by the common association of uranium- and thorium-bearing minerals with acid and alkaline rocks (e.g. granites and nepheline syenites), and in considerably greater quantities with their pegmatites. The most probable averages for common rocks and meteorites may be summarized as follows:—

TABLE I.

Type of Material.	Average per gram of rock. Radium,[3] in grams $\times 10^{-12}$.	Average per gram of rock. Thorium, in grams $\times 10^{-5}$.
Igneous Rocks.[2]		
Acid volcanic	3·1	2·9
Acid plutonic	2·7	
Intermediate volcanic	2·1	1·7
Intermediate plutonic	1·9	
Basic volcanic	1·1	0·5
Basic plutonic	0·9	
Ultra-basic	0·5	n.d.
Meteorites.		
Stone	0·25	n.d.
Iron-stone	0·10	n.d.
Iron	0·00	n.d.
Sedimentary Rocks.		
Argillaceous	1·5	1·1
Arenaceous	1·4	0·5
Calcareous	0·9	<0·1

3. The Density Stratification of the Earth.

The view that the earth is coarsely stratified according to the densities of its constituents is one suggested by—

(1) A comparison of the average density of crustal rocks with that of the earth as a whole.

(2) The structural characters of meteorites and the close correspondence in density and composition between their stony material and terrestrial ultra-basic rocks.[4]

(3) The structure of the earth's crust as indicated by the field relations and relative abundance of granite, basalt, and ultra-basic rocks.[5]

[1] Joly, *Phil. Mag.*, vol. xx, pp. 125 and 353, 1910, and Cong. Intern. de Radiologie et d'Electricité, p. 376, 1911; Fletcher, *Phil. Mag.*, vol. xx, pp. 102 and 770, 1910. See also Poole, *Phil. Mag.*, vol. xxix, 1915.

[2] Results for richly alkaline rocks, which are abnormally high in their radium and thorium contents, are omitted from this Table.

[3] Implying the series Uranium to Lead.

[4] Suess, *The Face of the Earth* (Eng. trans.), vol. iv, p. 544; Farrington, *Journ. Geol.*, vol. ix, p. 623, 1901; Merrill, *Am. J. Sci.*, vol. xxvii, p. 469, 1909; vol. xxxv, p. 509, 1913; Holmes, loc. cit., pp. 30–5, 1914.

[5] Von Cotta, *Geologische Fragen, Frieburg*, 1858, pp. 76–8; Green, *Vestiges of the Molten Globe*, pt. ii, p. 61, 1887; Daly, U.S.G.S. Bull. 209, p. 110, 1903; *Igneous Rocks and their Origin*, p. 162, 1914.

(4) The existence of surfaces of physical discontinuity within the earth as revealed by seismology.[1]

The broad conception of the structure of our planet which is suggested by these converging lines of evidence is that of a metallic core (average specific gravity = 7·8) occupying approximately half of the earth's total volume, surrounded by a thick peripheral shell (average specific gravity = 3·4) in which the silicate rocks are concentrated, becoming increasingly acid and alkaline as the crust (average specific gravity = 2·8) is reached. We are thus prepared for the conclusion that the radio-active elements are concentrated in the earth's outer shell, for the acid and alkaline rocks are just those which are richest in radium and thorium. It is an interesting fact that volcanic rocks, which are uniformly more acid and alkaline than their plutonic equivalents, are also richer in the radio-active elements. Rocks of gabbroid composition, which presumably underlie the immense granite and gneiss areas of the continents, contain less than a third as much radium and thorium as the granites. Ultra-basic rocks, which would seem to be comfortably at home only below the gabbroid zone, contain only a sixth as much. That the actual falling off in depth may be somewhat greater than these figures suggest, is indicated by the difference in radio-activity between volcanic and plutonic rocks. If the transfer of igneous magmas from levels corresponding to those at which we find stocks and batholiths, to those at which volcanic eruptions take place, is accompanied by so marked an increase in their content of the radio-elements, it seems probable that the whole upward journey may be marked by a progressive enrichment of a similar kind. Thus, even in rocks of the same composition, a decrease of radio-activity with depth is to be expected, but since the upward concentration must be mainly ascribed to gravitational differentiation,[2] and to the concentrating action of volatile fluxes, such an effect would certainly become less important as the depth increased.

So far, only the density stratification has been *assumed*, and the falling off of the radio-active elements in depth has been deduced as a natural consequence of that assumption. This was done to avoid any difficulty over the debated question of the inhibition of radio-activity by pressure. Conversely, if the independence of radio-activity be assumed, an assumption which, as I said before, is thoroughly justified, and indeed ceases to be an assumption, down to the limited depths with which petrologists are concerned, then the density stratification of the earth's crust follows as a natural consequence, as shown in the following discussion.

4. The Decrease of Radio-activity with Depth.

Since the view that the earth is getting hotter cannot be accepted, let us allow to radio-active heating all that can be theoretically granted to it, and assume that the total amount of heat lost from the

[1] Milne, Proc. Roy. Soc., A, vol. lxxvii, p. 365, 1906; R. D. Oldham, Q.J.G.S., vol. lxii, p. 456, 1906; vol. lxiii, p. 344, 1907; *Nature*, August 21, p. 635, 1913.

[2] In spite of their very high atomic weights, the radio-elements tend to be carried upwards on account of their association with the lighter components of rock-magmas.

earth by conduction and radiation is exactly made good by radio-thermal action. Taking the simplest possible distribution of the radio-active elements, let us suppose that the average content of the surface rocks is uniformly maintained down to the maximum possible depth consistent with the limited heat production allowed to it. The depth of such a radio-active layer is easily calculated from the data now available.

The total amount of heat Q lost by the earth is given by the equation

$$Q = 4\pi r^2 . k . d\theta/dx \qquad (1)$$

in which $4\pi r^2$, the area of the earth's surface, is taken as 51×10^{17} sq. cm.; k,[1] the average conductivity of rocks, is taken as 0·006 for granite and gneiss, 0·005 for average igneous rock, and 0·004 for basaltic or gabbroid rock; and $d\theta/dx$, the average temperature gradient near the surface of the continents, is taken as 0·00032° C. per cm. or 1° C. in 31·25 metres. Since granite is by far the most abundant rock over the continents, the most accurate result is likely to be obtained by using the largest value given for k above.[2] For the sub-oceanic rocks the assumption is made that the heat lost per unit area is equal to the corresponding amount for continental rocks. Substituting the suggested values in equation 1, the total heat loss Q is found to be $9·71 \times 10^{12}$ calories per second.

To determine the average amount of heat generated by the radio-active elements in each cubic centimetre of the crustal rocks, we must combine the average quantities of radium and thorium in the rocks with the respective amounts of heat produced by the two families of radio-active elements which are implied by the presence of radium and thorium. The latter factors are known with considerable accuracy.[3] Radium, implying the series Uranium to Lead (Radium G) in complete radio-active equilibrium, represents a generation of

[1] THERMAL CONDUCTIVITY OF ROCKS.

Igneous Rocks. Acid.		Igneous Rocks. Basic.		Sedimentary Rocks.	
Felspar	0·0058	Basalt	0·00415	Marble	0·0050
Quartz	0·0095	Basalt	0·0052	Sandstone	0·0050
Granite	0·0081	Trap-rock	0·0038	Sandstone	0·0055
Gneiss	0·0058	Basalt	0·00352	Slate	0·0048
Granite	0·0060			Chalk	0·0025
Granite	0·0053			Clay-slate	0·0027
Porphyry	0·0084				
Trachyte	0·0059				
Syenite	0·0044				
Mean for rocks = 0·0063		Mean = 0·00417		Mean = 0·00425	

[2] If it is thought that this value of k (0·006) combined with a temperature gradient of 0·00032° C. per cm. gives an unfairly high result, it should be remembered (1) that the tendency in measuring temperature gradients is always to under- rather than over-estimate, and (2) that the heat lost from the earth by igneous activity is not included in the product $k . d\theta/dx$.

[3] See Rutherford, *Radio-active Substances and their Radiations*, pp. 583, 650, 1913.

6×10^2 calories per gram per second; thorium, implying the series Thorium to Thorium E in complete radio-active equilibrium, represents a generation of $7{\cdot}5 \times 10^9$ calories per gram per second.

Taking the average composition of the earth's crust[1] as equivalent to equal quantities of acid (granitic) and basic (basaltic or gabbroid) plutonic rock types, with specific gravities respectively of 2·66 and 2·95, we obtain the following results from the figures given in Table I.

TABLE II.

Type of Rock.	Acid.	Basic.	Average.
Specific gravity.	2·66	2·94	2·8
Radium in grams per c.c.	$7{\cdot}18 \times 10^{-12}$	$2{\cdot}65 \times 10^{-12}$	$4{\cdot}91 \times 10^{-12}$
Thorium in grams per c.c.	$7{\cdot}71 \times 10^{-5}$	$1{\cdot}47 \times 10^{-5}$	$4{\cdot}59 \times 10^{-5}$
Heat produced from radium in calories per second per c.c.	$43{\cdot}1 \times 10^{-14}$	$15{\cdot}9 \times 10^{-14}$	$29{\cdot}5 \times 10^{-14}$
Heat produced from thorium in calories per second per c.c.	$57{\cdot}8 \times 10^{-14}$	$11{\cdot}0 \times 10^{-14}$	$34{\cdot}4 \times 10^{-14}$
A = Total heat production per c.c. of rock in calories per second.	$100{\cdot}9 \times 10^{-14}$	$26{\cdot}9 \times 10^{-14}$	$63{\cdot}9 \times 10^{-14}$

The volume of rock required to maintain the earth in a state of thermal equilibrium is clearly given by Q/A, and the depth D of the layer in which the radio-activity is concentrated is given by

$$D = Q/4\pi r^2 \,.\, A \tag{2}$$

Under the assumed conditions, the maximum temperature θ possible within the earth will be that at the bottom of the radio-active layer, and can be calculated from the expression[2]

$$\theta = AD^2/2k \tag{3}$$

Since from equations 2 and 1

$$AD = Q/4\pi r^2 = k d\theta/dx$$

we may also write

$$\theta = \frac{k(d\theta/dx)^2}{2A} \tag{4}$$

which gives the basal temperature in terms of known quantities without involving the composite factor D.

Substituting the values of A given in Table II we arrive at the following values of D and θ for the three types of rock material chosen for discussion:—

[1] Considered not only superficially but in depth also.
[2] Joly, *Radio-activity and Geology*, p. 272, 1909.

TABLE III.

Type of Rock.	Acid.	Basic.	Average.
k, thermal conductivity.	0·006	0·004	0·005
$d\theta/dx$, corresponding temperature gradient per cm.	0·00032° C.	0·00048° C.	0·00038° C.
D, depth of radio-active layer.	19 km.	70 km.	30 km.
θ, maximum temperature.	300° C.	1650° C.	570° C.

Of these results only that for basic rocks gives a temperature of the order required to explain the facts of vulcanism. The two others are manifestly absurd. Even if they be corrected to take into account the heat represented by the ascent of igneous materials through the crust (including the heat loss from volcanoes, fumaroles, solfataras, geysers, hot-springs, etc.) and a liberal allowance of 20 per cent of the earth's total loss of heat be assigned to this portion of it, the calculated temperature would still be far removed from the high values so forcibly demonstrated by vulcanism. The figures obtained for acid and basic rocks point to the way of reconciliation. Equation 4 indicates that A must decrease in depth if adequate temperatures are to be reached. That is to say, on the continents, where acid rocks predominate, the radio-activity of the rocks must decrease in depth; and a few trial calculations show that the decrease must be very rapid in order to allow the radio-active elements to persist to sufficient depths to give the requisite temperatures. This kind of decrease implies, as Table I clearly shows, a corresponding decrease in the acidity of the rocks and an increase in their density. The passage, at suitable depths, from granite to rocks of gabbroid composition would adequately accommodate the requirements.

Even in the case of average rock material the same argument holds. Under a continent of average composition the rocks in depth must soon give place to basic types. Briefly, the argument is that volcanic temperatures demand a rapid decrease of radio-activity with depth, and therefore a corresponding change in the composition of the igneous rocks which carry the radio-active elements.

The temperature arrived at for the basic rocks is satisfactory as it stands, but it has no meaning unless it be admitted—(1) that under the deeper and more permanent parts of the oceans the rocks are predominantly basic; (2) that the heat lost from the sub-oceanic rocks is about the same per unit area as that lost from the continents.

The first of these assumptions is supported by gravity measurements and the conception of isostasy, by the rocks themselves as exhibited in oceanic volcanic islands, and by the physical difference between sub-oceanic and sub-continental rocks which has been revealed by Oldham's interpretation of earthquake records. The second assumption is supported by the fact that the temperature gradients near the ocean borders are steeper than those well within the continents. The amount of heat issuing from the earth is proportional to the product of conductivity and gradient. Thus, if the oceans lie in heavy basaltic depressions with a lower conductivity than the lighter granitic elevations of the continents, it follows that the gradients to be expected would be steeper for the former case than the latter, if the average loss of heat be everywhere approximately equal. Moreover, such a steepening can be explained at least partially as a result of the earth's superficial features. Near the surface the isogeotherms are approximately parallel to the surface; at greater depths they tend to become more and more nearly spherical and independent of superficial irregularities. Under the continents successive isogeotherms will therefore be more widely apart than their continuations under the oceans. That such a difference may actually exist is suggested by the fact that volcanoes are much more abundant well within the oceans than they are in the continental masses.

It would appear, then, that the two assumptions to which we are led are not without foundation, and for the present purpose they may be admitted without further discussion. It now becomes important to notice that if the continents are essentially granitic, with basic rock below, and the sub-oceanic rocks predominantly basic with little granitic covering and in some places even none, then the radio-active elements must be more abundant on and below the continents than below the oceans. Exactly how much so depends on the thickness of the granite covering in each case. If, to give an example, we assume that in the continents one-third of the total quantity of radio-elements in any vertical section is confined to the upper zone of granite and that the remaining two-thirds are distributed in basic rocks below, then it would appear that under the oceans a similar vertical section would provide only two-thirds of the total quantity of radio-elements found in a continental section. This would be a necessary consequence of any igneous mechanism by which granite was originally concentrated in the continental areas. In such a case the depth of the radio-active layer under the ocean would be about 47 km. instead of 70, and (from equation 3) the maximum temperature would then be reduced to 750° C. Thus the same difficulty arises as before, and we are led to the final conclusion that even on the extreme view here taken of the sub-oceanic rocks, their radio-activity must decrease with depth in order to provide sufficiently high temperatures. Here, however, the necessity for decrease is less severe, for a consideration of equation 4 shows that a temperature of 750° C. corresponds to a gradient just below the floor of the ocean, which is the same as assumed for the continents. If the actual gradient is steeper than this so as to bring up the heat output to the continental standard, then the additional gradient must be due to some source of heat more effective under the oceans than under the continents (e.g. igneous activity from below, compression, etc.), which in turn would provide higher temperatures in depth.

5. The Law of Decrease.

Case 1.—In the present state of our knowledge, it is, of course, impossible to state with mathematical precision the rate at which radio-activity decreases in depth. The continental case suggested above, in which one-third of the radio-activity is confined to a granite shell (thickness 6·3 km.) and the remaining two-thirds to an underlying zone of basic rock (thickness 47 km.), would give a maximum temperature of nearly 1,000° C. This value is of the order required, and the conditions appear to agree fairly well with the probabilities of rock distribution.

The conditions, however, are not capable of being treated mathematically when stated in so crude a form. We require some law of decrease which can readily be stated mathematically so as to deal with the problem of a cooling earth as well as with volcanic temperatures. We have already seen that even in rock of uniform composition there is reason to believe that the radio-activity decreases with depth. Moreover, it is unlikely that the boundaries between successive zones of different density are as clearly cut as assumed in the above case. It is more probable that the lower portions of the acid shell are more basic than its upper parts, and similarly that the lower levels of the gabbroid sub-zone in turn approximate to the composition of the ultra-basic rocks beneath. It must be remembered that this variation of rock-types with depth refers to averages at each level and not to individual rock-masses. Igneous geology points to a natural antipathy between acid, basic, and ultra-basic types, so that it ought not to be assumed that there are levels at which intermediate types are characteristic, but only that the proportions of each main type vary at different depths. Combining the variation of rock-types with the suggested decrease of radio-activity in depth within any one rock-type, it would seem to be probable that the degree of heat generation decreases steadily from the surface downwards. The mathematical curve which can be made to agree most nearly with such a distribution is the exponential curve. We shall therefore assume an exponential decrease such that A_x, the heat generated per cubic centimetre at any depth x, is given by the equation—

$$A_x = Ae^{-ax} \tag{5}$$

in which a is the percentage decrease in heat generation per unit distance. This law of decrease is such that if at a depth d the radio-active generation of heat per unit volume of rock has diminished to $A/2$, or half its surface value, then at a depth $2d$ the heat production will be reduced to $A/4$ or $A/2^2$, at a depth $3d$ to $A/8$ or $A/2^3$, and generally at a depth nd to $A/2^n$.

The value of a can be calculated from the total heat, q, which issues from each unit area of the earth per second.

$$q = \int_0^\infty Ae^{-ax}\,dx = A/a$$
$$= k\,d\theta/dx$$
$$\therefore \quad a = \frac{A}{k\,d\theta/dx} \tag{6}$$

The half-value depth d is given by

$$1/a = 1·443\,d \tag{7}$$

The maximum temperature, θ, for the steady state is

$$\theta = A/a^2k \tag{8}$$

and the temperature θ' at any depth x is

$$\theta' = A/a^2k\,(1 - e^{-ax}). \tag{9}$$

We may now proceed to apply these formulæ to different cases with the data already provided.

Case 2: Acid Rock.—Here $a = 5{\cdot}2 \times 10^{-7}$ and $\theta = 700°$ C. This certainly does not reproduce the actual conditions, for d, the half-value depth, is only reached at about 13 km., so that rock of basaltic composition would only be reached at a depth of 25 km. Again, the value of k adopted for acid rocks is too high to carry down to such depths, and the temperature obtained is insufficient.

Case 3: Basic Rock.— (a) Here $a = 2{\cdot}1 \times 10^{-7}$ and $\theta = 1580°$ C. if the temperature gradient 0·00032° C. per cm. be used in equation 6.

(b) If, however, we use the gradient appropriate to basic rocks, viz. 0·00048° C. per cm., then a becomes $1{\cdot}4 \times 10^{-7}$ and the maximum temperature is 3560° C.

(c) If now this result be applied to the sub-oceanic rocks it becomes necessary to make, as before, a correction for the smaller content of the radio-active elements under the oceans than that under the continents. Taking these contents respectively as 1 : 2/3, then the gradient due to radio-activity is only 0·00032° C. per cm., so that the temperature is just what we obtained at first, 1580° C. Any remaining part of the gradient would then, as already stated, be attributable to some other source of heat, which would correspondingly increase the temperature in depth.

Case 4: Average Rock.—(a) Here $a = 4{\cdot}0 \times 10^{-7}$ and $\theta = 800°$ C. when a temperature gradient of 0·00032° C. per cm. is used.

(b) Using the more appropriate gradient of 0·00038° C. per cm., the value of a is found to be $3{\cdot}4 \times 10^{-7}$ and θ becomes 1200° C.

The latter result is the most probable yet obtained and deserves further attention. The average radio-thermal conditions for the earth seem to lie between case 1 for the continents (temp. 1000° C.) and case 3 (a) or 3 (c) for the oceans (temp. 1580° C.). Case 4 (b) thus fairly represents the temperature requirements. At a depth of 50 km. the temperature would be 1100° C. (equation 9) according to the average conditions of case 4 (b). At the same depth the temperature under the oceans, case 3 (c), would be 1400° C., and under the continents, case 1, 900° C. Case 4 (b) may therefore be accepted as a fair representation of the earth's average conditions, stated in a way suitable for mathematical treatment. The data on which it is based are as follows:—

k, thermal conductivity . .	$= 0{\cdot}005$ C.G.S. units.
$d\theta/dx$, temperature gradient .	$= 0{\cdot}00038°$ C. per cm.
A, total heat production per c.cm. at the surface .	$= 26{\cdot}9 \times 10^{-14}$ calories per sec.

It must be carefully noticed that these data do not represent the facts at any actual place. They are simply an attempt to express the facts of rock distribution, both superficially and in depth, in a single average capable of being treated exponentially. I have tried various other more direct methods, but without success. The problems which await solution cannot be attacked except by an indirect method such as the above, which has the conspicuous advantage of giving results in harmony with volcanic phenomena.

6. Conclusions.

1. From the distribution of the radio-active elements among igneous rock-types and the variation of igneous rock-types in depth, it is deduced that the radio-active elements are specially concentrated in the earth's crust, the density of distribution being greatest near the surface, and falling off in depth.

2. Direct experiments show that radio-active disintegration, and therefore the consequent heat generation, are unaffected by temperatures of 2500° C. and by pressures of 160 tons to the square inch, conditions which correspond with those of a depth of 50 miles (80 km.) within the earth.

3. Thermal considerations demand, as an alternative to inhibition (which as shown in 2 cannot be assumed), that the radio-active elements should be almost altogether confined to an outer shell of the lithosphere.

4. Volcanic temperatures indicate that the density of distribution of the radio-active elements falls off rapidly with depth, the rate of decrease being perhaps greater under the continents than under the oceans.

5. For mathematical purposes radio-activity and heat generation are assumed to decrease exponentially in depth, this being a law of decrease which can be adapted to agree with the limiting conditions of rock distribution (superficially and in depth) and volcanic temperatures. The case chosen for further mathematical treatment is discussed in the preceding section, case 4 (*b*).

(Part II will appear in the March Number.)

III.—Brachiopod Morphology: Types of Folding in the Terebratulacea.

By J. ALLAN THOMSON, M.A., D.Sc., F.G.S.

IN descriptions of Recent and Tertiary Terebratulids at least, the type of folding is often hardly mentioned, and is left to be inferred from the figure, in spite of the fact that Douvillé[1] in 1879 showed that it might be even of generic importance. Buckman[2] has more recently drawn attention once more to the importance of this character and has shown that its due consideration may lead to fruitful results in classification. The object of this paper is to point out further cases in which it has been neglected.

Shells showing no folding, with a rounded anterior margin and a plane commissure, are said by Buckman to be in the 'lenticular stage'. Three primary modes of development of such a form are possible; it may become—

1. Dorsally uniplicate, i.e. with a single fold on the dorsal valve opposing a sinus in the ventral valve, or

[1] H. Douvillé, "Note sur quelques genres de Brachiopodes (Terebratulidæ et Waldhemiidæ)": Bull. Soc. géol. Fr., ser. III, tom. vii, pp. 251–77, 1879.

[2] S. S. Buckman, "Brachiopod Morphology: *Cincta*, *Eudesia*, and the Development of Ribs": Quart. Journ. Geol. Soc., vol. lxiii, pp. 338–43, 1907.

2. Ventrally uniplicate ('*Nucleatæ*' of Douvillé), i.e. with a single fold in the ventral valve opposing a sinus in the dorsal valve, or
3. It may pass to the *Cincta* stage, in which fold opposes fold and sinus opposes sinus.

By the development of a sinus in the middle of the single dorsal fold, the dorsally uniplicate forms may become dorsally biplicate, and by a similar process the ventrally uniplicate forms may become ventrally biplicate ('*Coarctatæ*' of Douvillé). Buckman has also shown how alternate multicarination and multicostation may arise from the dorsally uniplicate forms, and opposite multicarination from forms in the *Cincta* stage. It is hardly necessary to point out that a dorsally uniplicate form cannot become ventrally biplicate, or a ventrally uniplicate form become dorsally biplicate.

Douvillé recognized the above facts more or less clearly, and used them successfully to separate many forms from *Terebratula* and *Waldheimia*, but unfortunately in three cases (*Liothyris*, *Macandrevia*, and *Neothyris*) he was mistaken as to the type of folding actually exhibited by the shells. His mistake apparently arose from a belief that a straight front or an anterior truncation was necessarily due to a retardation of the *Cincta* type, for he placed these three genera among the '*Cinctæ*'. Now a straight front or an anterior truncation may be combined with dorsal uniplication, as is well shown, for example, in Kitchen's figures of Jurassic *Terebratulæ* from India.[1] It may equally well be combined with ventral uniplication. In cases where the plication is not of a pronounced type the only safe guide is the course of the anterior commissure. This is plane in shells in the lenticular or the *Cincta* stage, is arched upwards in shells showing dorsal uniplication, be it ever so slight, and is bent downwards in shells showing ventral uniplication. A slight tendency to uniplication can always be recognized by the arching up or bending downwards of the anterior commissure.[2]

Sub-family Terebratulinæ.

In *Liothyrina*[3] *vitrea*, the genotype, the anterior commissure describes a broad, rather flattened arch, and the type of folding is therefore incipiently dorsally uniplicate, and not of the *Cincta* type as supposed by Douvillé, and similarly all the recent species placed in that genus are either non-plicate in the lenticular stage, or are incipiently dorsally uniplicate. Buckman[4] considers that the chief characters of the genus (apart from its loop characters) are the possession of a thin test and of four internal radiating furrows which serve for the attachment of the pallial sinuses, characters seen in the Chalk species assigned to *Liothyrina*, viz. *Terebratula carnea*,

[1] *Palæontologica Indica*, ser. IX, vol. iii, pt. i, 1910.
[2] Apparently in certain species of *Terebratulina* a retardation of the *Cincta* type can set in after the shell has assumed an incipient dorsal uniplication.
[3] *Liothyris*, Douvillé, 1879, being preoccupied by *Liothyris*, Conrad, 1875, the name was changed to *Liothyrina* by Oehlert in 1887.
[4] "Antarctic Fossil Brachiopoda, etc.": Wissensch. Ergebnisse der Schwed. Südpolar Exped., 1901–3, Bd. iii, Lief. vii, pp. 26–7, 1910.

T. subrotunda, and *T. semiglobosa*. Now of these three species, according to Davidson's figures, *T. subrotunda* is non-plicate, *T. carnea* has incipient dorsal uniplication, while *T. semiglobosa* is incipiently biplicate. In *Liothyrina*, therefore, if we accept Buckman's view of the genus, the species form a series from non-plicate to dorsally biplicate.

Terebratula itself is a dorsally biplicate shell, the forerunners of which, in Buckman's[1] view, would be non-plicate, perhaps uniplicate, before becoming biplicate. We may go further and state that every Tertiary species with the *Terebratula* type of loop is either non-plicate, dorsally uniplicate, or dorsally biplicate. No ventrally uniplicate forms are known in the Tertiary of either hemisphere, although there is a Jurassic genus, *Glossothyris*, Douvillé, which has this type of folding. Where, then, are we to place the recent abyssal species *Terebratula wyvilli*, Davidson, subsequently assigned by Davidson to *Liothyris*, a shell showing pronounced ventral uniplication? Its type of folding excludes it at once from *Liothyrina* and *Terebratula*, and it can hardly be supposed that *Glossothyris* could retain its characters with such persistence through so many millions of years. It seems necessary to create a new genus for its reception, but I refrain from this step in the hope that some one who has access to specimens will compare its internal characters with those of *Glossothyris* and obtain evidence of another kind that will make the way clearer. It may further be suggested that the sub-family Terebratulinæ, in which Schuchert includes indiscriminately shells showing series from non-plicate to dorsally biplicate, to ventrally biplicate, and to extreme folding of the *Cincta* type, is unwieldy and in need of revision.[2]

Sub-family Magellaninæ.

Turning next to the Magellaninæ, we find a much greater uniformity in type of folding. Douvillé considered that *Magellania flavescens*, the genotype of *Magellania*, belonged to the '*Coarctatæ*', that is, that it possessed ventral biplication, while *M. lenticularis* belonged to the *Cinctæ*, and he therefore made the latter species the type of a new genus, *Neothyris*. In the case of *M. flavescens*, Buckman, apparently overlooking Douvillé's statement, declared that it showed a little indication of ventral uniplication. I think, however, that Douvillé was justified, for in many specimens the anterior commissure shows a dominant ventral uniplication on which is imposed the beginnings of biplication. In any case it cannot be doubted that many Australian Tertiary species assigned to *Magellania*, e.g. *M. gambierensis* (Etheridge fil.),[3] possess distinct ventral biplication.

In the case of *M. lenticularis*, however, Douvillé was mistaken, for it is not in the *Cincta* stage, but, as its anterior commissure shows, is just passing out of the lenticular stage to incipient ventral

[1] "Brachiopod Nomenclature: the Genotype of *Terebratula*": Ann. Mag. Nat. Hist., ser. VII, vol. ix, pp. 525–31, 1907.
[2] See further remarks on this point under the Dallininæ.
[3] Ann. Mag. Nat. Hist., ser. IV, vol. xvii, p. 19, pl. ii, figs. 4*a*–*d*, 1876.

uniplication. In other words, *Neothyris* and *Magellania* belong to the same series of folding, viz. from non-plicate to ventrally biplicate, and on this ground, therefore, there is hardly reason for *Neothyris*, which, as a matter of fact, has been suppressed by most modern authors. Digressing from consideration of types of folding, I may point out that there are other grounds on which *Neothyris* may stand as a very good genus. *N. lenticularis* differs from *M. flavescens* in exactly the same way as *Pachymagas tehuelca*[1] differs from *Terebratella dorsata*, viz. in the possession of a bifurcating septum and extremely thickened socket-ridges and cardinal process, as against a simple septum, thin socket-ridges, a lamellar hinge-plate, and a small transverse cardinal process.

Every Recent and Tertiary species referable to *Bouchardia*, *Magasella*, *Pachymagas*, *Terebratella*, *Neothyris*, and *Magellania* belongs to the same series of folding, viz. from non-plicate to ventrally biplicate, and this may be taken as a character of the Magellaninæ.[2] Alternate multicostation arising directly from a smooth stage is found on some species of *Terebratella* and *Magellania*, but this is superposed on the ventral plication. Schuchert, however, includes in this sub-family the genera *Cœnothyris* and *Ismenia*, the former of which is distinctly dorsally uniplicate, while the latter possesses an alternate multicarination, which, as Buckman has shown, is probably derived from a dorsally uniplicate form. These two genera, therefore, should be removed from the Magellaninæ.

Sub-family Dallininæ.

Turning next to the Dallininæ, we find a much greater diversity. In *Dallina* itself, *D. septigera* (the genotype) is dorsally biplicate, *D. raphælis* is the same, while *D. floridana* is dorsally uniplicate, all belonging to the series lenticular to dorsally biplicate. *Terebratula grayi*, Davidson, which was also referred by Beecher to *Dallina*, is a ventrally uniplicate shell with alternate multicostation, and cannot therefore belong to *Dallina*. There seems to be no difficulty in referring it to *Magellania*, as it apparently possesses the Magellaniform hinge-plate and cardinal process. Now *Dallina* and its forerunners must all belong to the series non-plicate to dorsally biplicate, but for the immediate forerunner, *Terebratalia*, Beecher[3] has chosen for genotype *Terebratula transversa*, Sowerby, a shell which is undoubtedly ventrally uniplicate. This was the more unfortunate, as the actual species on which he established a different ontogenetic series from that of *Terebratella*, s.str., was *Terebratella obsoleta*, Dall, which is a dorsally uniplicate form. *Terebratula transversa*, Sow., and *Terebratula coreanica*, Adams & Reeve, two ventrally uniplicate forms from the North Pacific which have been referred to *Terebratalia*, are,

[1] H. von Ihering, Ann. Mus. Nac. Buenos Aires, tom. ii, p. 332, 1903.

[2] Apparent exceptions are the New Zealand Tertiary forms *Terebratula gaulteri*, Morris, and *Terebratella sinuata*, Hutton, which are dorsally uniplicate, but these have proved to be smooth Rhynchonellids.

[3] C. E. Beecher, "Revision of the Families of the loop-bearing Brachiopoda. The Development of *Terebratalia obsoleta*, Dall": Trans. Conn. Acad., vol. ix, pp. 376–99, pls. i and ii, 1893.

I believe, true *Terebratellæ*, and if this be so *Terebratalia* becomes a synonym of *Terebratella*. Before this position can be disputed it is necessary to study their young stages and show that they are not comparable to those of *Terebratella*.[1] Beecher was apparently misled by the general separation of the Dallininæ and the Magellaninæ in the northern and southern oceans. Jackson[2] has already shown that the Dallininæ have a species (*Macandrevia diamantina*) in Antarctic waters, and it now appears that the Magellaninae have at least three genera, *Magellania*, *Terebratella*, and *Magasella*, represented in the North Pacific.

But even if it should be shown that *Terebratalia* is distinct from *Terebratella*, there can be no question, on account of the difference in folding, that *Terebratella obsoleta* cannot be referred to *Terebratalia*, and a new genus is necessary for its reception, and this I now propose.

Dallinella, genus nov.
Genotype, *Terebratella obsoleta*, Dall.[3]

Shell non-plicate to dorsally uniplicate. Loop passing in growth through Platidiform, Ismeniform, and Muehlfeldtiform stages, attaining finally a stage resembling *Terebratella*. The non-plicate *Terebratula spitzbergenensis*, Dav., and the dorsally uniplicate *Terebratella Mariæ*, A. Adams, may apparently also be referred to *Dallinella*.

We have, therefore, in the Dallininæ a recent stock of shells, ranging from non-plicate to dorsally biplicate, represented by the genera *Dallina* and *Dallinella*. Amongst fossil stocks with the same types of folding may be mentioned *Kingena*, *Epicyrta*, *Cœnothyris*, *Plesiothyris*, and the multicostate genera *Ismenia*, *Eudesia*, and *Flabellothyris*.

But those are also genera which go through growth-stages similar to those of *Dallina* so far as loop-development is concerned, but are ventrally plicate. *Macandrevia* appears to be non-plicate in the genotype *M. cranium* and not in the *Cincta* stage as Douvillé thought, but *M. diamantina*, Dall, is clearly a ventrally uniplicate form. The Recent species of *Muehlfeldtia* are incipiently uniplicate, and *Platidia* also shows the beginnings of ventral uniplication. We should expect to find a genus of Recent or Tertiary shells in this series with Terebratelliform loop which might be regarded as the forerunner of *Macandrevia*. Possibly this lack is supplied in the species *Terebratula frontalis*, Middendorff, which agrees with expectations in being ventrally uniplicate, in possessing an incomplete foramen and a short median septum not reaching posteriorly to the umbo, but we are left in ignorance by Davidson as to the nature of the hinge-teeth and

[1] The hinge-plates of these species appear to be Terebratelliform, and Davidson has stated that the growth stages of *T. coreanica* resemble those of *T. rubicunda*. If *T. grayi* is correctly placed in *Magellania*, the presence of *Terebratellæ* in the Northern Pacific is only to be expected.

[2] J. W. Jackson, "The Brachiopoda of the Scottish National Antarctic Expedition": Trans. Roy. Soc. Edin., vol. xlviii, pp. 367–90, 1912.

[3] In case Beecher has made any mistake in his identification of this species, with which I am unacquainted, I further desire to define the genotype as the species actually figured by Beecher under the name of *T. obsoleta*, Dall.

whether dental plates are present or not. A peculiar feature in this species is the divided hinge-plate. It has points of resemblance to some Magaselloid stocks, but does not agree with any known to me. In any case this species cannot find a place in *Terebratella* or *Dallinella*. Among fossil genera referred to the Dallininæ which show ventral uniplication are *Aulacothyris*, *Trigonosemus*, *Orthotoma*, and *Camerothyris*, while *Antiptychina* is ventrally biplicate. It is open to question, however, whether these fossil genera really belong to the Dallininæ or to the Magellaninæ until the mode of development of their loop is known.

Finally, there are amongst Recent shells ascribed to the Dallininæ some which show anterior retardation of the *Cincta* type. Of these the best example is *Terebratula blanfordi*, Dunker, which was described and figured by Davidson as a *Terebratella*, but was later referred to *Laqueus* by Dall[1] on account of its loop characters. This species has a well-marked mesial sinus on each valve and an excavate front, and the same characters are possessed in a lesser degree by *Laqueus rubellus* (Sow.) and *L. jeffreysi* (Dall).[2] Of the remaining species ascribed to *Laqueus*, *L. pictus* is non-plicate and apparently in the lenticular stage, though there is a tendency towards a straight front, but *L. californicus*, which is the type of the genus, occupied an anomalous position, for according to Davidson's figures and descriptions it shows the beginnings of ventral uniplication. It appears as if in this case a stock in the lenticular stage were evolving in two directions, giving rise on the one hand to species with ventral uniplication and on the other to species with *Cincta* retardation. As the process has not gone very far, it seems hardly necessary to separate the *Cincta*-like forms under a new genus at present.

Among fossil genera ascribed to the Dallininæ which show anterior retardation of the *Cincta* type are *Cincta*, *Microthyris*, *Zeilleria*, *Trigonella*, and *Trigonellina*.

As in the case of the Terebratulinæ, then, we have in the Dallininæ genera belonging to each of the three series of folding. It is not suggested that *Laqueus blanfordi* is necessarily more nearly related to *Cincta* than to *Dallina* or *Macandrevia*. A great deal more must be learned before we are in a position to know the relationship of the various members of the Dallininæ to one another, and in this connexion a study of the beak characters, hinge-plate, and cardinal process may be of considerable service.[3]

The simplicity of types of folding in the Magellaninæ and the complexity in the Dallininæ at least suggest that these two subfamilies are not of equal taxonomic value.

[1] Proc. U.S. Nat. Mus., vol. xvii, pp. 724–6, 1895.

[2] Originally described by Dall as *Frenula jeffreysi*, and later by Davidson as *Laqueus californicus*, var. *vancouveriensis*. See Dall, loc. cit.

[3] These characters are proving of considerable aid in separating different stocks of the Magellaninæ among New Zealand Tertiary shells which have arrived independently at Magellaniform loops.

IV.—The Work of Professor Lacroix on the Laterites of French Guinea.

By L. Leigh Fermor, D.Sc., A.R.S.M., F.G.S., Geological Survey of India.

(Continued from January Number, p. 37.)

IV (*b*). *Zone of Concretion.*

In this zone the phenomenon of *départ* or *leaching* is carried to a finish, and though of little significance in the case of the gibbsitic laterites of the diabases, gabbros, and syenites, since these from the beginning of alteration in the zone of leaching have been deprived of the greater part of the elements to be removed, yet in the case of the mica-schists it is of great importance. But in every case there is an accentuation of a phenomenon already evident in the preceding zone, namely the *emigration of iron towards the surface,* where it becomes concentrated.[1] At the same time concretionary phenomena, often resulting in the separation of the hydrates of iron and aluminium one from the other, become increasingly important and reach their maximum development quite close to the surface, where they lead to the formation of a resistant crust (*cuirasse*), in which hydroxide of iron acts as cement; this hydroxide may even become sufficiently abundant to constitute an ore of iron, particularly in the case of certain diabases, and above all of peridotites.

In Professor Lacroix' opinion the formation of a continuous crust depends on definite topographical conditions (horizontal plateaux or gentle slope of the ground).[2] Thus the author regards as inadmissible the hypothesis according to which the formation of the *iron-ores* of Guinea is ascribed to the mechanical concentration of iron oxides by running water;[3] instead, in the cases described by Professor Lacroix, the hydroxide of iron has superposed itself on the pre-existing elements of the superficial crust: "il s'accumule de bas en haut."

Corresponding to the three modes of alteration in the zone of leaching, resulting, respectively, in the formation of gibbsitic laterites, ferruginous laterites, and kaolins and lateritic clays, Professor Lacroix finds three types of end-products resulting from the completion of the process of lateritization in the zone of concretion. These are gibbsitic, ferruginous, and bauxitic types, respectively, of which the latter type in particular tends to be pisolitic.

Gibbsitic Types.—The readiness with which iron oxide takes part in concretionary changes is manifest to the eye, but the mobility of

[1] Lacroix notices that this ascension of iron towards the surface was observed long ago by Hislop (1857, Lacroix gives 1863), and later by Maclaren (1906), in the laterite of India, and by Arsandaux in that of Western Africa and of the Congo, and by many other authors.

[2] While this is doubtless true from the point of view of the actual result, Professor Lacroix overlooks the circumstance that on steep slopes the products of weathering are rapidly removed by erosion, so that lateritic products have no chance of accumulating.

[3] Lacroix remarks that this theory has already been proposed by Holland (Geol. Mag., 1903, p. 62) to explain the formation of the low-level laterites of India, to which Holland attributes a detrital origin. Lacroix does not, however, regard the two cases as comparable.

TABLE I.—ANALYSES OF LATERITES DERIVED FROM NEPHELINE-SYENITES,

Original Rocks.	Nepheline-syenites.			
Locality.	Kassa I.	Roume I.	Kassa I.	Fotabar.
Position in Section.	Fresh rock.	Zone of leaching.	Zone of concretion.	Zone of leaching.
Name of Rock.	Nepheline-syenite.	Porous gibbsitic laterite.	Compact gibbsitic laterite.	Clay (gibbsitic).
Number.	1	2	3	4
SiO_2	56·88	2·21	0·37	35·14
TiO_2	0·29	0·12	0·90	0·70
Al_2O_3	22·60	55·83	57·12	40·08
Cr_2O_3	—	—	—	—
Fe_2O_3	0·97	5·22	7·41	4·12
FeO	2·19	—	—	—
CaO	1·33	0·24	0·17	0·45
MgO	0·56	0·19	—	0·21
Na_2O	8·30	0·49	0·26	—
K_2O	5·57	0·27	0·37	—
P_2O_5	0·08	—	—	—
H_2O	0·98	30·47	33·71	17·84
Insoluble	0·34(Cl)	5·74	0·30	1·46
	100·09	100·78	100·61	100·00
Mineral Composition:—				
$Al_2O_3 . 2SiO_2 . nH_2O$ (clay) [1]	—	5·0 (3)	0·8 (2)	76·6 ($2\frac{1}{3}$)
$Al_2O_3 . 3H_2O$ (gibbsite)	—	82·5	86·9	15·6
$Al_2O_3 . H_2O$ (colloidal)	—	—	—	—
$2Fe_2O_3 . 3H_2O$ (limonite and stilpnosiderite)	—	6·1	8·6	4·8
Hematite	—	—	—	—
$TiO_2 . H_2O$	—	0·1	1·1	0·8
Insolubles	—	5·7	0·3	1·5
	—	99·4	97·7 [2]	99·3 [3]

Notes.—The mineral compositions have been recalculated by me, because Lacroix takes no account of the insolubles or titania, and often omits to state the composition of the *argile*.

[1] The value of n is shown in brackets in each case, n being 2 per kaolinite.

[2] Omitting a surplus of 2·08 % water above that required per $n = 2$ in the silicate. It is equivalent to 37 H_2O if taken into the silicate.

[3] Lacroix terms this rock *argile bauxitique*, but describes the presence of gibbsite.

Diabases, and Peridotites.

Diabases and Gabbros.			Peridotites.		
Mt. Bougourou.			Mt. Kakoulima.	Railway, km. 10.	?
Fresh rock.	Zone of leaching.	Zone of concretion (cuirass).	Fresh rock.	Zone of leaching.	Zone of concretion (cuirass).
Diabase.	Porous argillaceous (*silicatée*) gibbsitic laterite.	Compact gibbsitic laterite.	Peridotite.	Porous argillaceous ferruginous laterite.	Ferruginous laterite[6] (iron-ore).
5	6	7	8	9	10
51·27	5·83	1·30	38·32	12·67	—
0·70	1·29	1·03	0·28	0·55	—
12·36	37·03	60·19	2·66	12·59	4·80
—	—	—	0·16	—	0·20
3·29	31·73	3·91	4·35	46·84	83·50
6·16	—	—	11·78	—	—
10·66	0·19	0·17	2·74	0·04	—
13·26	0·06	—	36·22	1·26	—
1·60	—	—	0·16	—	—
0·41	—	—	0·06	—	—
0·11	—	—	—	—	—
0·40	23·02	32·00	3·38	15·32	10·18
—	0·96	1·40	—	10·73[5]	1·70[5]
100·22	100·11	100·00	100·11	100·00	100·38
—	12·5 (2)	2·8 (2)	—	30·1 (3½)	—
—	43·2[4]	87·9	—	2·9	7·3
—	4·5	1·9	—	—	—
—	37·1	4·6	—	54·7	52·9
—	—	—	—	—	38·3
—	1·6	1·3	—	—	—
—	1·0	1·4	—	10·7	1·7
—	99·9	99·9	—	98·4	100·2

[4] Lacroix regards all the Al_2O_3 as present as gibbsite, presumably assigning to the *argile* a lower state of hydration than $n=2$.

[5] Picotite.

[6] Sample obtained by powdering twenty-five pieces of red ore.

the alumina, although less apparent, is none the less real, as Professor Lacroix demonstrates by means of chemical analysis (compare analyses Nos. 3, 7, 10 with Nos. 2, 6, 9, see Table I), and has followed in detail under the microscope; little by little the ferruginous products, which, in the diabases and syenites, occupy the places of the heavy silicates, are replaced by gibbsite, which, in addition, fills in all the spaces in the rock. This mineral must be regarded, therefore, as rather soluble in the underground waters, as is obvious when one recalls cases of crystalline gibbsite in geodes and cracks in laterites and ores from Guinea, India, Brazil, and New Caledonia. The final result of the transport and recrystallization of gibbsite is the formation of *granular crystalline rocks* of relatively coarse grain composed almost entirely *of gibbsite.*

Ferruginous Types.—In the case of laterites derived from peridotites the zone of concretion, owing to the poverty of the original rock in alumina, corresponds with the ferruginous crust. This crust shows every variety of concretionary form of *limonite* and *stilpnosiderite*; and at the actual surface the limonite becomes more or less dehydrated with appearance of red tints, indicating doubtless the formation of *hematite* (see analysis No. 10, Table I, p. 79).

Bauxitic Types.—In contrast to the zone of concretion of the laterites derived from diabases and syenites, the characteristic of the zone of concretion capping the kaolins and lateritic clays of the zone of leaching of the mica-schists, granites, and gneisses, is that *the aluminium hydrate,* which, little by little, replaces the aluminous silicate, *assumes at first the colloidal form* (see analyses Nos. 11, 12, 13, Table II). Although, in this case, gibbsite is often present, it is always accompanied by an important and often predominant proportion of colloidal hydrates, and Professor Lacroix maintains that this crystalline mineral is a product of transformation of the colloidal forms; and by means of the evidence of thin sections he proves his contention in the case of the pisolitic laterites.

Pisolitic Laterites.—Speaking generally, one of the characteristics of the crust or cuirass is the abundance of pisolitic forms. It has long been held that pisolites in general have been formed in waters in movement, and recently this idea has been used to explain the formation of the pisolitic bauxites of Arkansas. But although Professor Lacroix admits the legitimacy of such an opinion in the case of the siliceous or calcareous pisolites of thermal springs, he regards it as indefensible in the case of laterite. On the contrary, the pisolites of laterite, like those found in clays formed by the decalcification of limestone, have been formed *in situ* in a medium in a state of rest, and in general have not suffered transport since their formation; their form, degree of regularity, and size depend on the physical state of this medium. The best condition for the formation of pisolites is, according to Lacroix, the existence of a homogeneous medium, enclosing few or no solid elements insusceptible of concretionary re-arrangement, unless in small grains; this explains the abundance of pisolites in the lateritic crusts of mica-schists, clays, and alluvium.

Professor Lacroix here (p. 342) refers to the section of my classification of laterites instituted for *lake laterites*, a name suggested for any of the pisolitic laterites that can be proved to have been formed by deposition from solution in bodies of water on the analogy of the Swedish lake ores of iron. Professor Lacroix has not seen personally in Guinea any pisolitic rocks, formed necessarily by a process of this nature, and remarks that the conditions realized in the temporary pools of water on the surface of the *bowals*[1] are sufficient to explain all the facts observed. It should be noted that I did not suggest that pisolitic laterites in general would prove to be lake laterites, but proposed this division to allow for eventualities, suggesting only that two particular cases of pisolitic limonite might prove to belong to this division. In view of Lacroix' account of the pisolitic laterites of Guinea, I am quite prepared for the future to show that true lake laterites are a very rare type. Obviously, however, there must be some relationship between laterites deposited chemically in lakes, and those formed in small pools on the surface of already existing laterites.

Continuing, Professor Lacroix remarks that ferruginous pisolites are found in the cuirass of all the lateritic types, colloidal hydroxide of iron being a ubiquitous product; but the same is not the case for very aluminous pisolites. In Guinea they are not found in the lateritic cuirass of the nepheline-syenites, and they are rare in that of the basic rocks; but on the contrary they are common in the cuirass of the mica-schists, granites, and clays, not only on account of the conditions of the medium already referred to, but also for another reason.

In the gibbsitic laterites the aluminous hydrosol circulates in the zone of concretion in contact with gibbsite formed from the commencement of alteration and disseminated everywhere, and the crystals of this mineral serve as nuclei, determining an almost complete crystallization. But, in the alteration of mica-schists, the whole of the alumina is liberated from its silicated compounds in the form of a gel, and exists in part in this condition in the cuirass; it can thus easily rearrange itself into pisolites, as long as crystallization has not set in. Whenever, as at Fatoya and Siguiri, gibbsite is seen in these pisolites, the irregularity of its disposition, and the absence of regular fibro-lamellar structure starting from a centre, leave no doubt as to its secondary origin.

Judging from the examples given in this memoir, it might be thought that the persistence of the colloidal state bore some relation to the composition of the aluminium hydrate, the hydrate with one molecule appearing to be abundant in the bauxitic laterites, and that with three molecules in the laterites formed from the diabases and syenites. The crystallization of gibbsite in the pisolites would then be, as M. Arsandaux thinks, the result of hydration.[2] But the

[1] Name in the Foula language (p. 273) for vast horizontal or undulating tracts in Guinea, either quite bare, or covered with a meagre vegetation of grasses, *Cyperus*, and semi-aquatic plants.

[2] Lacroix notes that Maclaren (Geol. Mag., 1906, p. 546) supposes that in India gibbsite results from hydration, contrarily to the opinion of Holland, who regards laterite as characterized by a dehydration (Geol. Mag., 1903, p. 65). Judging from Lacroix' researches it will be seen that there is probably little

existence in Arkansas[1] and elsewhere of pisolitic laterites formed entirely of aluminium hydrate with three molecules of water, largely in the colloidal state, and only crystallized in cracks, shows that if this cause can be admitted in certain cases, it is not the general rule.

The Hardening of Laterites.—This is regarded as a non-essential property of laterite, due to the evaporation on exposure to the air of the quarry water contained in the colloidal hydroxides and silicates, and particularly in the hydroxide of iron.[2] It is only seen in those laterites containing these products in abundance, and is absent from the gibbsitic laterites derived from the diabases and syenites.

(To be concluded in the March Number.)

REVIEWS.

I.—College Physiography. By R. S. Tarr; edited by L. Martin. pp. xxii + 836, with 10 coloured maps and 503 text-figures. New York: Macmillan, 1914. Price 15*s.*

THE late Professor R. S. Tarr was well known in this country as one of the ablest exponents of the modern American school of physical geography. Besides publishing during his lifetime several small textbooks of physiography, he projected a large and comprehensive work on the same subject. At the time of his death in 1912 some twenty chapters of the book were written; after consultation with Mrs. Tarr and some leading American geographers, Professor Lawrence Martin, of the University of Wisconsin, undertook to supply the remaining chapters and to edit the whole work. The result is a book of over 800 pages, with some 500 illustrations. As stated in the editor's preface, it is intended "for use in elementary physical geography courses in universities, colleges, and normal schools, for supplementary reference-reading by high-school students who are using a more elementary text, and for general reading by laymen of mature years". The first reflection that suggested itself to the reviewer is that American college students cannot be in the habit of doing their serious reading in arm-chairs, such a proceeding in this instance being barred by the enormous weight of the book, which scales nearly 4 lb. avoirdupois.

change in the state of hydration of the oxides of aluminium and iron once they have been deposited, except in the cuirass, where the limonite and stilpnosiderite tend to lose their water with formation of hematite, whilst the aluminium hydrates are unaffected.

[1] Lacroix was able to visit the bauxite deposits near Little Rock last summer, and concludes that they must be regarded as laterites formed from alkaline-syenites, with kaolin characterizing the zone of leaching and bauxite the zone of concretion.

[2] It is interesting to recall here Holland's suggestion that the loss of water accompanying the hardening of laterite is due to the crystalline affinity of Fe_2O_3 in two molecules of limonite leading to the formation of crystalline hematite with rejection of water.

The original twenty chapters written by Professor Tarr deal with the lands and the oceans, while Professor Martin is responsible for one chapter on the ocean and for the whole section dealing with atmospheric phenomena. The bias of the book is certainly towards the geographical and geological side, since out of 814 pages of text 636 pages are devoted to the lithosphere. As would naturally be expected, the treatment is distinctively American; the great majority of the illustrations (of which, by the way, no list is given) are taken from that continent, though other parts of the world, when illustrating special points, are by no means neglected. In a book of this size and comprehensiveness it is difficult and perhaps invidious to single out special portions for criticism, but it may be mentioned that the sections dealing with glaciation in all its forms are particularly good, and will be read with interest by geologists and geographers on this side of the Atlantic. The very detailed study of the glaciation of the United States and Canada carried out in recent years must eventually have an important influence on the final settlement of that much-debated and still unsolved problem, the nature of the Pleistocene glaciation of the British Isles and especially of Eastern and Central England.

A chapter of great general interest deals with the relief features of the earth's surface, and this is illustrated by an excellent series of photographs of relief-models of the continents; the model of North America, for example, will serve to bring before the student in the clearest manner the threefold division of that continent—the mountain areas in the east and west and the central plain. The picture of the model of Eurasia, however, is much less successful, as it shows Europe only as a minor appendage in a lop-sided position in the north-western corner, and the scale is too small to be of much service.

Perhaps the least satisfactory portion of the book is that dealing with mountains, and especially the sections describing the mountain systems of Europe. The author's ideas as to the relative ages and mutual relations of the fold-systems of Western Europe are by no means clear, as shown by the following sentence (p. 535): "The low Urals extend north and south along the eastern boundary of Russia, and an ancient mountain range extends from northern Scandinavia through the British Isles to Brittany in France." The second clause gives no clear picture of the relations in time and space of these systems, and certainly does not give an impression of several sets of folds, of very different ages, intersecting at acute angles, as is actually the case. Fig. 340, which is somewhat vaguely labelled "The Alps in Austria, rising above the snow-line", apparently a view of Innsbrück, is scarcely calculated to impart to the intelligent but untravelled American an adequate idea of the general appearance of a European mountain range. On the other hand, many of the pictures are very good, taking into account their small size and the fact that they are printed as text-figures. The coloured plates are all well-chosen examples of the beautiful contour-maps issued by the United States Geological Survey, and to each chapter is appended an admirable bibliography.

R. H. R.

II.—Canada Department of Mines, Geological Survey; Museum Bulletin No. 3, Geological Series No. 19. The Anticosti Island faunas. By W. H. Twenhofel. 35 pp. and i pl. 30 October, 1914.

Bulletin No. 4, Geological Series No. 20. The Crowsnest volcanics. By J. D. MacKenzie. 37 pp. i pl. numbered as p. 37. 19 November, 1914.

Bulletin No. 5, Geological Series No. 21. A *Beatricea*-like organism from the Middle Ordovician. By Percy E. Raymond. 19 pp. pls. i–iv numbered as pp. 13–19. 23 November, 1914.

E. BILLINGS' "Catalogues of the Silurian Fossils of the Island of Anticosti" were issued in November, 1866, and assumed considerable importance in the history of North American Palæozoic palæontology from the number of species therein described. It was high time therefore for a renewed study of these beds and for their correlation with the numerous divisions that have subsequently been recognised both in North America and elsewhere. Dr. Twenhofel's paper is preliminary to a memoir that will ultimately be issued by the Geological Survey of Canada, and states his conclusions as follows: (1) "Billings' statement that the section is complete from base to summit and contains no stratigraphic break [although Billings admits a palæontological break] is sustained." (2) [As a result presumably of this completeness], "many of the species have ranges through greater thicknesses than the same species have in other regions." (3) There is a great difference between the faunas of the north and south shores of the island, corresponding to lithologic differences and hence to original differences of environment. (4) On the north the rocks are shaly and sandy, on the south they contain more corals and are more calcareous but not so thick.

The various series and formation names are taken from a previous paper by Schuchert and Twenhofel (1910) and are correlated as follows:—

System.	Series.	Formation.	N. America.	Britain.	Norway, etc.
Silurian.	Anticosti.	Chicotte.	Irondequoit. Rochester.	Wenlock.	Etage 8.
,,	,,	Jupiter River.	Clinton.	Upper Llandovery.	Etage 7.
,,	,,	Gun River.	Cataract and Brassfield. Alexandrian.	Lower Llandovery.	Etage 6.
,,	,,	Becsie River.			
Ordovician.	Gamachian.	Ellis Bay.	No equivalent.	Upper Bala.	Etage 5.
,,	Richmond.	Charleton.	Richmondian of the interior.	Middle Bala.	Borkholm.
,,	,,	English Head.			
,,	Utica.	Macasty Shale.			

The following new generic and subgeneric names are proposed: *Palæofavosites*, n.g. of Favositidæ; *Strophoprian* or *Strophoprion*, n. s-g. of *Strophonella* (?, the genus is not stated); *Virgiana*, n.g. of

Pentamerana; *Protozeuga*, n.g. of Terebratuloids, with genotype *Waldheimia mawi* Davidson; *Lissatrypa*, n.g. of Atrypidæ with genotype *L. atheroidea* = *Athyris lara* Davidson non Billings.

The Crowsnest volcanics, so named from the Crowsnest Pass in Alberta, near which they occur, consist of tuffs, agglomerates, and a few flow rocks. Their interest lies mainly in the fragments of which they are composed. These, according to Mr. MacKenzie, are in order of abundance, trachytes, blairmorites, and latites. The trachytes are rich in soda and comprise varieties bearing ægirite-augite and melanite. Blairmorites, of which the name was suggested by C. W. Knight, are ultra-alkaline, soda-rich porphyries, containing phenocrysts of analcite in quantities up to 71 per cent. This occurrence links up the alkaline rocks of Montana with the ultra-alkaline intrusive mass of Ice River, B.C., so that the series form a related group "the Rocky Mountain Petrographic Province".

Anything that throws light on the problematic *Beatricea* is welcome, and Dr. Raymond's careful description of his new genus *Cryptophragmus* is illustrated by some excellent photographs. He follows Nicholson and Professor Parks in referring the Beatriceidæ to the Stromatoporoids, and regards the inner septate tube as an axial support secreted by the zooids of the ensheathing colony.

Certain remarks as to dates of publication contained in our review of the last part of this Bulletin (Geol. Mag., November 1914, p. 525) appear to have been not altogether justified. We have in consequence been favoured with a set of the papers contained in that part, each in a dated wrapper of its own and with separate pagination—a fact to which attention has been conscientiously drawn by a rubber stamp. We are therefore bound to suppose that the separate papers were actually available on those dates. This of course leaves us still wondering why it should have taken two months and a half for a copy of the whole to reach London. Bulletin No. 3 took one month and a half, and Bulletins 4 and 5 a little over a month. The war is really not enough to account for this. We are, however, very glad to see that each paper is now issued as a separate number of the Bulletin, so that there need in future be no confusion regarding either date or pagination, and it should be quite possible to publish each part on the actual date given. We cannot conclude these slightly critical remarks without recognising the generous freedom with which the Canadian authorities distribute these valuable publications, a liberality so great that no price is marked either on the works themselves or on the announcements which invite those interested to make application for them to the Director of the Geological Survey.

F. A. B.

III.—Engineering Geology. By Heinrich Ries and Thomas L. Watson. pp xxvi + 672, with 225 illustrations in the text and 104 plates. New York, John Wiley and Sons, Inc.; London, Chapman & Hall, Ltd., 1914. Price $4.00 net.

THIS treatise embodies the courses of teaching given by the authors to the students at the Universities of Connell and Virginia respectively. It affords a comprehensive survey of the principles of geological science, and a careful study of it will enable the engineering student to face with confidence the many problems, so varied in character, that he may encounter in the course of his professional career. The scope of the book is wide, and covers such diverse subjects as the character of rocks in respect of their use for building purposes or for road-making, the structure of rocks so far as it may affect tunnelling operations and building dams or reservoirs, the conditions which determine the flow of underground waters, the character of soils in connexion with the disposal of sewage and the purification of water, the ingredients of cements and clays, the sources of coal and oil, and the nature of ore deposits. The value of the book to the engineering student is enhanced by the fact that the discussion always follows strictly practical lines; instances, mostly drawn from American occurrences, illustrating the point in question being described. The ample illustrations are well chosen and excellent in character, and the bibliography of American literature at the close of each chapter enables the reader to prosecute his study further if he so desires. The volume is, in fact, one that should find a place on the shelves of every civil engineer.

In the early chapters a brief survey is given of such parts of mineralogy and petrology as are immediately related to the subject. The necessary brevity has entailed some looseness in expression; it may, for instance, be questioned whether the definition of a mineral as "any natural inorganic substance of definite chemical composition", or of a crystal as "a solid bounded by flat and somewhat smooth surfaces, called faces, symmetrically grouped about imaginary lines as axes", be logically satisfactory. In the discussion of the physical characters of minerals it is pointed out that the colour may be natural, i.e. bound up with the essential composition, or exotic, i.e. due to the presence of some foreign pigment, and the authors say in the case of iron that "according to the amount present the mineral will ordinarily exhibit some shade of green, brown, or even black", but do not mention the difference of tint depending upon the state of oxidation of the iron. The characters of the principal rock-forming minerals are described in the order—silicates (the largest group), oxides, carbonates, sulphates, phosphates, and sulphides. The discussion being based upon the microscopic appearance, little is said about the optical properties. The second and third chapters deal with the general characters of rocks, divided into the customary groups—igneous, sedimentary, and metamorphic—and their structure and metamorphism The authors then pass on to the weathering of rocks and the soils resulting therefrom, the surface and underground waters, landslides, wave action, lakes, and glacial deposits. In a subsequent chapter the different kinds of building stones in use are fully treated, and their capacity to withstand the disintegrating effects of weathering, mechanical stress, and extreme heat is discussed in considerable detail. It is pointed out that the quarrymen, and we might add the general public, use the term granite in a far wider sense than is now usual in science. The properties of limes and cements, and the rocks used in road making are described, and the concluding chapter is taken up with the important subject of ore deposits. Maps showing the distribution of the particular rocks under discussion are plentifully supplied, and reference to the volume is immensely simplified by means of excellent subject and locality indices.

IV.—Limits of the Secondary and Tertiary Periods.

IN a recent number of the Proceedings of the Palæontological Society of America (Bulletin Geological Society of America, vol. xxv, p. 321, 1914) Professor H. F. Osborn gives an interesting summary of a discussion held at a meeting of the Society as to the precise line that should be drawn between the Secondary and Tertiary periods. Very divergent views seem to have been expressed. Thus Dr. F. H. Knowlton endeavoured to show that palæobotany indicates that no sharp line of demarcation exists between the two periods, and expressed his belief that the real division occurred long before the close of the Age of Reptiles. On the other hand, most of the disputants seem to have tended to the traditional view that the extinction of the Dinosaurs marks the termination of the Cretaceous period and that the only important survival of a Cretaceous reptile till Tertiary times is that of *Champsosaurus*. Several papers resulting from this discussion have been published in the Proceedings of the Geological Society of America, especially by W. D. Matthew ("Evidence of the Palæocene Vertebrate Fauna on the Cretaceous–Tertiary Problem") and Barnum Brown ("Cretaceous–Eocene Correlation in New Mexico, Wyoming, Montana, Alberta"). Dr. W. J. Sinclair has also contributed an important paper to this discussion (Bulletin American Museum Natural History, 1914, p. 297).

V.—Brief Notices.

1. British Museum (Natural History).—The "Return" ordered by the House of Commons for 1913–14 (price 1*s.*) is as interesting as its predecessors. A systematic record of accessions to the Geological and Mineralogical Departments is given. Among the principal items are the Piltdown skull, etc.; specimens illustrating the Holocene deposits of Newquay and the North of Ireland; Trilobites from the Comley Sandstone; large collections of Carboniferous and Devonian corals; three Silurian corals figured by Thomas Pennant in 1757; 760 Carboniferous and Devonian fishes (Traquair Collection); 1,400 Carboniferous and 300 Cretaceous fossils from Ireland (Wright and Donaldson Collections); the Pennant Collection of minerals; rocks from Ecuador (Whymper Collection); a fine series illustrative of the ruby-mines of Burma; and numerous exceptionally fine mineral specimens.

2. Ealing Scientific and Microscopical Society.—A report of Dr. Smith Woodward's lecture on "Fossil Man" appears in the Report for 1913–14, and some notes on "Ancient Hanwell" by Mr. H Beasley. Although the latter deals with historic times there are points of interest in topography for those who study prehistoric conditions.

3. Norfolk and Norwich Naturalists' Society.—The only paper of interest to geologists in the Transactions of this Society (vol. ix, pt. v) is an excellent sketch of the life of Horace Bolingbroke Woodward by his friend and colleague Clement Reid, illustrated by a good portrait.

4. Norwich.—The Report of the Norwich Castle Museum for 1913 has reached us. Beyond the accession of a series of Gault fossils from Elstow, Bedfordshire, there seems nothing of importance to record in the geological collections, but the general work carried on in the Museum under Mr. Frank Leney, the curator, is most excellent, and merits the highest commendation.

5. A Norfolk Geologist.—In the Bulletin (173) of the New York State Museum are reproduced two leaves from the notebooks of Richard Cowling Taylor, the well-known Norfolk geologist, who emigrated to the United States about 1830 and followed up his researches in that country. These are printed in colours, deal with American geology, and seem to connect him with the New York State Geological Survey, a connexion apparently previously unknown.

6. Rugby.—The Report of the Rugby School Natural History Society for 1913 is not very encouraging so far as geology is concerned. It is satisfactory to learn that the re-naming and re-arrangement of local fossils in the School Museum is proceeding, but there must be new fossils to be found at Napton and a systematic search should be made.

7. Liverpool Geological Society.—The President's (C. B. Travis) address issued in the Proceedings (vol. xii, pt. i) dealt with peneplanation in the British Islands, and forms a good summary of the subject. The record of Triassic footprints is continued by H. C. Beasley and F. T. Maidwell; some curious ctenoid markings on Triassic slabs are described by Beasley as possibly equisetiform in origin; and a paper by W. T. Walker describes the Liassic outcrop near Whitchurch, Shropshire.

8. The Proceedings of the Yorkshire Geological Society for 1914 contains a valuable paper by Dr. Wheelton Hind (p. 25) commenting upon the interesting facies of the Millstone Grit fauna obtained from the Cayton Gill Beds, which has "a large number of species common to it and the *Dibunophyllum* Beds of the Carboniferous Limestone, and does not contain the *Goniatite* fauna and its associated Lamellibranchia subsequently met with in the slate beds between the different members of Millstone Grit". The North American *Prothyris elegans* also found in the Millstone Grit of Scotland and at Congleton Edge is reported by Dr. Hind as occurring in the Grit at Colsterdale.

9. Paisley Abbey.—During excavations for the foundations of the restored choir of Paisley Abbey a quantity of hazel-nuts, pieces of hazel-wood, and willow stumps with other vegetable matter, were found. These are discussed in a paper by the Rev. C. A. Hall and Duncan Smith in the Trans. Paisley Phil. Inst. for 1914, where, incidentally, a good deal of information relating to the district has been brought together.

10. Fossil Mammals from the Crimea.—In a memoir entitled *Mammifères fossiles de Sebastopol* (Mem. Comité Geologique, n.s., livr. 87, Petrograd 1914) A. Borrissiak describes a mammalian fauna of Middle Sarmatian age which in many respects is very similar to the widely distributed fauna of the Pikermi type. The most important new genus is *Achtiaria*, which is a member of the Giraffidæ and not very remote in structure from *Samotherium* and *Okapi*: the dentition and some limb-bones are described. The author also gives an account of new species of *Tragoceros* and *Aceratherium* and of a new variety of *Hipparion gracile*.

11. Indian Geological Terminology.—This is a list of terms used by writers on Indian geology, now arranged in alphabetical order by Holland & Tipper in the Memoirs of the Geological Survey of India (vol. xliii, pt. i, 1913). It is modelled on the well-known American publications of similar nature, and gives the general history of the word and the present fixation of its meaning, if that meaning has changed since the introduction of the term itself.

12. In the Memoirs of the Geological Survey of India (vol. xli, pt. ii, pp. 148–245, 1914) Dr. L. Leigh Fermor contributes an interesting account of the geology and coal resources of Korea State, Central Provinces. The geological formations represented are: 1, Deccan Trap; 2, Gondwana, (*a*) Supra-Barakars, (*b*) Barakars, (*c*) Talchirs; 3, Archæan. The geology corresponds generally with the physical division into three plateaux. The lowest, that of Patna and Khargaon, is largely composed of rocks of the Talchir formation. On it rest two outliers of the Barakar rocks, comprising the Kurasia and Koneagarh Coal-fields, and these are outliers of the second or Sanhat plateau. The third or Deogarh plateau corresponds with the Supra-Barakar rocks.

13. In the Records of the Geological Survey of India (vol. xliv, pt. i, pp. 41–51, 1914), Dr. W. A. K. Christie describes a carbonaceous aerolite which fell near Chabra, in the Native State of Tonk, Rajputana, on January 22, 1911. The Tonk meteorite, as it is called, is chiefly interesting on account of its highly carbonaceous character, the chemical analysis showing it to contain no less than 2·70 per cent of carbon; the composition of the carbonaceous matter is uncertain. Under the microscope the stone appeared as a structureless, irregularly cracked mass, and, though no chrondritic structure was apparent, it should be classed as K (coaly chrondrite) in Brezina's classification.

14. Mining Districts of the Dillon Quadrangle, Montana, and adjacent Areas. By Alexander N. Winchell. United States Geological Survey, Bulletin 574. pp. 191, with 16 figures and 8 plates. Washington, 1914.

The region carefully described in this memoir lies just south of Butte, and measures about 49 miles wide east to west and 60 miles long. Gold placer-mining dates back as far as 1852 and was wonderfully productive; by the present day the diggings have been worked out, but the life of placer-mining has been prolonged by dredging operations. At the same time the deep mines have proved of considerable importance. The future outlook is not bright owing to the apparent exhaustion of the ore bodies, and the low prices recently ruling for silver, lead, and copper. The geological structure was largely determined by intrusion from below of the great Boulder batholith—mainly a quartz-monzonite—which seems to have penetrated important areas in Tertiary times. The igneous rocks include a wide range of types. The different mines are described in detail, and a copious index is given at the close of the memoir.

15. The Fernando Fossiliferous Sandstones.—Mr. Walter A. English's paper (University of California Publications, Bull. Dept. of Geology, November, 1914) on the Fernando group of fossiliferous sandstones and shales of Newball, California, is interesting as giving the results of an attempt to decide the age and relationship of beds which have been for a number of years indeterminate. Mr. English concludes that the beds in question are probably of basal Pliocene and Upper Pliocene or Pleistocene age respectively. He gives detailed accounts of the result of his collecting in various horizons and describes seven new species (two of Lamellibranchia and five of Gastropoda).

16. Mollusca of the Marine Miocene of California.—In the Bulletin of the Department of Geology of the University of California, vol. viii, No. 7, Mr. Bruce Martin gives descriptions of seventeen new species and varieties of Gastropoda and one of Lamellibranchia from the late Marine Neocene of California. These descriptions have been prepared in advance of a paper dealing with the correlation of the Pliocene beds of the middle and west coast of California during his recent investigation, of which Mr Martin obtained the material from which the new species are forthcoming.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *December* 16, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

A lecture was delivered by Professor W. M. Flinders Petrie, D.C.L., LL.D., F.R.S., F.B.A., on the Palæolithic Age and its Climate in Egypt.

He said that the classes of worked flints peculiar in Egypt are: (1) Irregular, with broad unregulated fractures. (2) Rounders, flaked in all directions to an edged disc. (3) Hoofs, very thick, rudely domed with an obtuse edge. (4) Lunes, with obtuse edges. (5) Crescent scrapers. Irregular flints, similar to those from St. Acheul, are found in high Nile gravels.

The regular European types occur exactly like those classed as Chellean and Acheulian. The Mousterian forms are so often found in various periods that they cannot be assigned without evidence of age. The Aurignacian survive into the early civilization. The large class of flints from the Fayum desert comprises all the Solutrean types, and also Robenhausian forms. The flakes of the early civilization (8000 to 6000 b.c.) are identical with Magdalenian.

Views of the Nile cliffs show the general nature of the country and conditions. Successive changes of level are indicated by (1) the collapse of immense drainage caverns far below present level; (2) the filling of valleys with debris up to 650 feet above the present sea-level; (3) the gouging-out of fresh drainage-lines through the filling; and (4) rolled gravels on the top of cliffs 800 feet above sea-level, since when there has been no perceptible denudation by rain. The great extent of these elevations and depressions is likely to be connected with similar movements at Gibraltar, which are believed to synchronize with the movements of glacial periods in Northern Europe. The evidence of the flint ages agrees with this connexion.

Lantern-slides were exhibited by Professor W. M. Flinders Petrie in illustration of his lecture. The photographs will be published in *Ancient Egypt* for April, 1915.

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2. *January* 6, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Silurian Inlier of Usk (Monmouthshire)." By Charles Irving Gardiner, M.A., F.G.S.

The Usk inlier lies a few miles north of Newport (Mon.). Between the coal-fields of South Wales and the Forest of Dean the Old Red Sandstone is bent into an anticline, the axis of which runs very nearly north and south. This has been denuded away to the west of Usk, and Silurian beds have been exposed, the rocks seen being of Ludlow and Wenlock age.

In the southern part of the inlier the Silurian rocks are arranged in two anticlinal folds, the axes of which run nearly north and south and dip southwards. These folds are separated by a fault. The western one is named the Coed-y-paen Anticline, the eastern one the Llangibby Anticline. The Old Red Sandstone is believed to rest unconformably on the Ludlow Beds along much of the margin of the Coed-y-paen Anticline; and beneath the Ludlow Beds, which are about 1,300 feet thick, come 35 to 40 feet of a Wenlock Limestone, which covers Wenlock Shales; of these latter some 850 feet are seen. It is impossible to separate the Ludlow Beds into an upper and a lower series, owing to the absence of the Aymestry Limestone. They are composed mainly of sandy shales and sandstones above, and of sandy shales with layers of calcareous nodules or of calcareous bands below.

Dayia navicula is a common fossil up to 240 feet from the top of the Ludlow Shales, and *Holopella gregaria* and *H. obsoleta* occur only in the uppermost beds.

At their base the Ludlow Beds seem to pass conformably down into the Wenlock Beds, and the Wenlock Limestone is probably not at the summit of the Wenlock Shales. The Wenlock Limestone occurs either in irregular layers separated by sandy shales, or in massive beds largely made up of crinoid fragments. Corals are rare in it.

The Wenlock Shales below the limestone are divisible into an upper portion, which consists of sandy shales and sandstones, and a lower portion composed of mudstones. The Coed-y-paen Anticline has been much affected by pressure, the hard Wenlock Limestone Bed has been fractured in no fewer than twelve places, and portions of it driven in on to the soft underlying shales.

In the northern part of the area there is much alluvium and drift; consequently, although no Wenlock Limestone is now to be seen beyond the Wenlock Shales, it is possible that the limestone may occur beneath the drift, as, when last exposed, the Wenlock Shales are seen dipping north-eastwards, and beyond the drift Ludlow Beds are observed near Clytha. The Llangibby Anticline extends as far north as Cwm Dowlais, and shows Ludlow Beds resting upon Wenlock Limestone, the anticline ending against an east-and-west fault. North of Cwm Dowlais nothing but Ludlow Beds are seen between the Coed-y-paen Anticline and the Old Red Sandstone, from both of which they are faulted.

An account of the Ludlow Beds along the western and eastern sides of the inlier is given, and a large amount of evidence with regard to the ages of the rocks at numerous exposures is produced in the form of lists of fossils. The fossils have all been named by Dr. F. R. Cowper Reed, who contributes an appendix in which several new species and varieties are described in detail.

2. "Some observations on Cone-in-Cone Structure and their relation to the Origin." By Samuel Rennie Haselhurst, M.Sc., F.G.S.

In a brief review our state of knowledge is summarized, and the deductions of other investigators are analysed.

The author then outlines the phenomenon of megascopic pseudo-stromatism, and certain tectonic features which are always associated with cone-in-cone structure in areas where it is greatly developed. He points to the disadvantage accruing from many observers not having seen it in situ on a large scale, and shows how a simulation of horizontality in stratification marks what he takes to be the key to the diagnosis of this structure.

Two typical areas are described:—

(1) The St. Mary's Island – Tynemouth district of the D_5 Coal-measures of Northumberland.
(2) The Hawsker – Robin Hood's Bay – Ravenscar district of the North Riding of Yorkshire.

The specimens collected in these areas are unique, and some dozen types from other areas, including Sandown, Portmadoc, Olney, Somerton, Lyme Regis, and Merivale Park, are examined in detail with reference to—

(1) Evidence furnished by distorted fossils.
(2) Chemical composition.
(3) Geometrical similarities.
(4) Microscopic structures.

The author critically examines the accepted hypothesis that cone-in-cone structure is something essentially due to crystallization.

He describes the results of some high-pressure mimetic experiments, aided by a Royal Society grant which he now gratefully acknowledges. These experiments were designed to produce this structure, and reveal what the author believes to be many new points on the origin of concretions and cone-in-cone in particular. The experiments are new, inasmuch as the media used, namely, brittle, semi-plastic, and plastic, are enclosed in tunics of varied design, and then subjected either to a high uniform hydrostatic pressure or to a direct thrust. The results are in many ways analogous to those of Ewing, Goodman, and Daubrée, who, it is remarked, did not attempt to explain cone-in-cone structures.

The author concludes from the evidence—

(1) That cone-in-cone is not due to crystallization, but is a mechanically produced structure due to great and localized pressure.
(2) That it is closely allied to the phenomenon known as pressure solution.
(3) That cone-in-cone structure is closely associated with other rock-structures which are mutually indicative the one of the other, and also of their mode of origin.

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3. *January* 20, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

1. "The Geology of the District around Machynlleth and Llyfnant Valley." By Professor Owen Thomas Jones, M.A., D.Sc., F.G.S., and William John Pugh, B.A., of the University College of Wales, Aberystwyth.

In an introduction a brief account is given of the physical features, general succession, and structure of the area, and reference is made to the work of previous investigators, especially Walter Keeping. For the major group the classification applied in 1909 to the district around Plynlimmon and Pont Erwyd is adopted, but slight differences are introduced in the arrangement of the minor groups. The classification is as follows:—

VALENTIAN (SILURIAN).	C. YSTWYTH STAGE.	Pale mudstones with numerous laminated grit-bands.		
	B. PONT ERWYD STAGE.	*b.* Derwen Group. 190 feet.	5. Zone of *Monograptus halli.*	Pale-blue and greenish mudstones, with bands of dark graptoliferous shales, and some thin green flags.
			4. Zone of *Monograptus sedgwicki.*	
			3. Zone of *Monograptus regularis.*	
			2. Zone of *Monograptus leptotheca.*	
			1. Zone of *Mesograptus magnus.*	
		a. Cwmere Group. 334 feet.	3. *Monograptus* spp. beds.	Dark rusty weathering shales and limestones.
			2. Zone of *Diplograptus acuminatus.*	
			1. Zone of *Glyptograptus persculptus.*	'Mottled Beds' and blue mudstones.
HARTFELL (ORDOVICIAN).	A. PLYNLIMMON STAGE.	Ty'n-y-maen Group.	Dark mudstones, grits, and some conglomerates.	

The distribution and character of these beds are described. The 'Mottled Beds' form the base of the Silurian and rest sharply on the underlying beds, and there is evidence of complete discontinuity at this level; they have proved of great service in elucidating the structure. The *Monograptus* spp. beds contain graptolites which elsewhere pertain to the zones of *Monograptus triangulatus*, *M. cyphus*, and *M. acinaces*; but another zone, that of *M. atavus*, has not been proved, although it probably occurs. The Derwen group consists of a regular alternation of mudstones and shale-bands with graptolites, which have also proved of service in mapping. Only a small thickness of the Ystwyth stage occurs, and no subdivisions are attempted.

The rocks are sharply folded, and sometimes overfolded, towards the east. Their axes range approximately north-north-east and south-south-west; the folds in the central area pitch northwards, but north of the Dovey a southerly pitch sets in. Each large fold is composed of a number of smaller folds having parallel axes, and changing in pitch more frequently than in the larger folds. Strike-faults of considerable magnitude range nearly parallel with the folding axes, and are in all cases overthrusts towards the east.

Of greater interest are the transverse faults ranging nearly east-north-east and west-south-west. Most of these are small, but their course across the higher ground is indicated by well-defined notches in the ridges that they cross. Two of these faults, the Pennal and Llyfnant Faults, are shatter-belts. The Llyfnant Fault displaces several folding axes, and overthrusts to the east on the north side. Its vertical displacement is on an average about 300 feet, but its horizontal displacement is usually over 3,000 feet. It may therefore be called a 'tear-fault'. Both the Llyfnant and the Pennal Faults exercise some influence upon the drainage system of the area.

A brief comparison of the succession with other districts is added.

2. "The Geology of the District between Abereiddy and Abercastle (Pembrokeshire)." By Arthur Hubert Cox, M.Sc., Ph.D., F.G.S.

The district is situate north-east of the area occupied by the pre-Cambrian rocks of St. Davids, and it is bounded on its northern side by the Pembrokeshire coast. Although some parts of this district have already been the subject of geological investigation, yet the stratigraphy and structure of the greater part is now described for the first time. Abereiddy itself has been, since the time of Hicks, a type locality for the Llanvirn Beds, but observations recently made by Professor O. T. Jones showed that the sequence required reinvestigation. It has now been found that the Ordovician rocks of the district do not succeed one another in a simple upward sequence, but that they have been thrown into great folds and sometimes even overfolded. The folds have subsequently been broken by extensive strike-faulting. The limbs of the folds increase in steepness as the pre-Cambrian massif is approached. This folding brings up strips of Cambrian rocks, the presence of which on the North Pembrokeshire coast was previously quite unsuspected.

There is a complete sequence of Ordovician rocks from near the base of the Arenig Series to high up in the Glenkiln Group. The lowest

Arenig rocks are a series of arenaceous strata (the Abercastle and Porth Gain Beds) which correspond to the '*Nesuretus* beds' of Ramsey Island. These strata are in faulted relationship to the Cambrian, so that the true base of the Arenig is not seen. The arenaceous beds pass upwards without break into *Tetragraptus* shales, which are in turn succeeded by the *bifidus* beds. Llanvirnian volcanic rocks are represented in one part of the district by the Llanrhian Volcanic Series, which begins high up in the zone of *Didymograptus bifidus*, and in another part by the *Murchisoni* Ash, which forms the base of the *D. Murchisoni* zone. The Llandeilo Series compares closely with that of Carmarthenshire, and does not contain any volcanic rocks as was at one time supposed.

Contemporaneous igneous rocks occur at two horizons: (1) keratophyres at a high horizon in the *Tetragraptus* shales, and (2) quartz-keratophyres (soda-rhyolites) towards the top of the *D. bifidus* beds. The intrusive rocks (diabases) belong to two types, (1) sub-ophitic quartz-diabases, and (2) ophitic diabases without quartz. Both types were intruded earlier than the main folding, and consequently earlier than the cleavage and faulting.

A great north-westerly line of disturbance—the Pwll Strodyr Fault—cuts across all other structures, and brings on entirely different groups of strata.

II.—Geologists' Association.

January 8, 1915.—George W. Young, F.G.S., F.Z.S., President, in the Chair.

The following lecture was delivered: "The Value of Graptolites to the Stratigraphical Geologist." By Miss Gertrude L. Elles, D.Sc.

The value of Graptolites as chronological indices depends upon the rapidity of their evolution and their wide distribution in space. The stages in evolution correspond to a great extent with the stratigraphical classification in common use, though at certain horizons there are characteristic 'bursts'. Detailed knowledge of the different species is in no way necessary for the recognition of the different horizons. The nature and value of a Graptolitic zone depends on the assemblage of characteristic forms.

III.—Edinburgh Geological Society.

December 16, 1914.—Dr. R. Campbell, President, in the Chair.

The following papers were read:—

1. "The Whinstone Dykes of the Great Cumbrae." By Thomas Bond Sprague, LL.D.

Dr. Sprague described the whinstone dykes of the island, and the raised beaches, which form prominent features of the topography of Cumbrae.

2. "The Breccias of Cheese Bay and Yellow Conglomerates of Weak Law." (Illustrated by lantern slides, specimens, and microscopic sections.) By T. Cuthbert Day, F.C.S.

The author describes some peculiar breccias to be found in the district of Cheese Bay, near Guilane, associated with the intrusive Monchiquite Basalt. From a study of some new exposures of these breccias, lately discovered, he concludes that they are contemporaneous with the intrusion itself, and are the results of movements of the igneous magma, constituting a final phase of the intrusion. He therefore names them "Intrusion Breccias" in order to distinguish them from breccias arising from faulting or ordinary earth movements.

The author also applies the experience gained in the study of the above breccias to the interpretation of a peculiar exposure of rock on the shore at Weak Law, near North Berwick, generally regarded as a conglomerate, and shows that this large mass of material, nearly 300 yards in length and above 50 yards across at the widest part, is in reality of an intrusive nature, and is very similar in its character to the intrusion breccias of Cheese Bay.

It is also suggested that the numerous scattered exposures of Monchiquite Basalt are really connected below the surface, and represent upper parts of a great intrusive mass or batholith rather than parts of an ordinary intrusive sill.

IV.—Liverpool Geological Society.

At a meeting of the above Society held on January 12, Mr. J. W. Dunn, F.G.S., read a paper on "Skiddaw and the Rocks of Barrowdale", in which he gave a comprehensive account of the two lower divisions of the Ordovician rocks of the Lake District. A full description was included of the Long Close Dyke in the Skiddaw slates at the south-east end of Lake Bassenthwaite, and of the contact metamorphism induced by it, which Mr. Dunn had studied in detail and compared with the larger and well-known effects of the granite intrusion. The dyke is about 12 feet wide and consists of a much decomposed mica-porphyrite or diabase. The total width of altered rock, including the dyke, is about 30 feet. The paper was well illustrated with photomicrographs and lantern slides, and a large and representative collection of Lake District rocks.

OBITUARY.

We regret to record the death of Mr. Arthur Roope Hunt, M.A. (Cantab.), F.L.S., F.G.S., which occurred at his residence, "Southwood," Torquay, on December 19, 1914, at the age of 71 years. We hope to give a notice of this well-known Devonshire geologist, who has been for the past twenty-five years a frequent contributor to the pages of the Geological Magazine.

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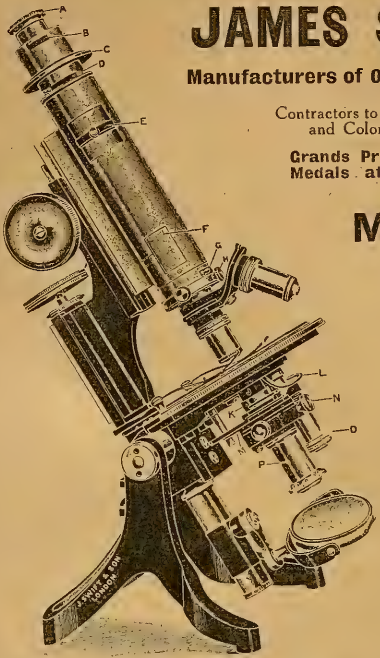

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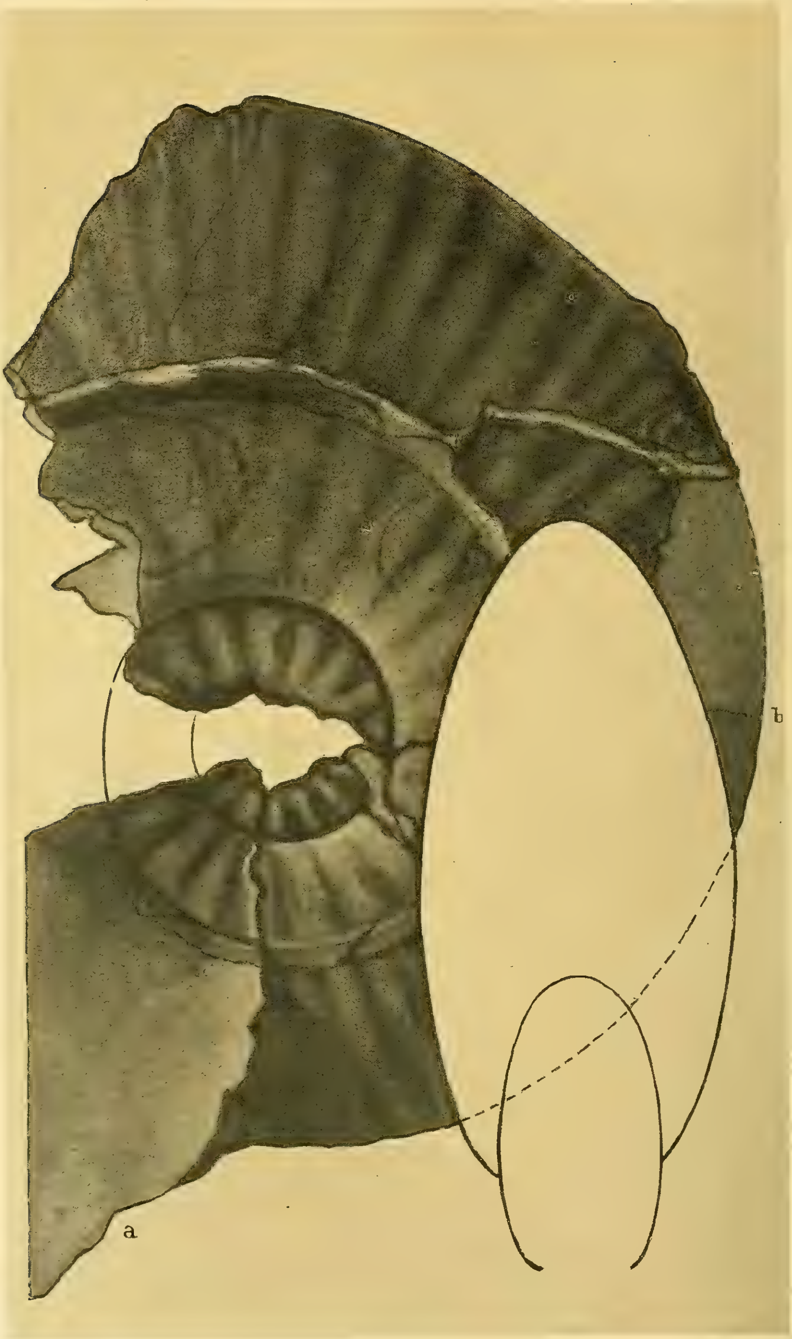

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ORIGINAL ARTICLES.

I.—On *Schlotheimia Greenoughi*, J. Sowerby, sp.

By L. F. Spath, B.Sc., F.G.S.

(PLATE IV.)

WHILE working at the Lower Liassic Ammonites of the Sowerby Collection, preserved in the British Museum (Nat. Hist.), the author happened to come upon one of the paratypes of *Ammonites Greenoughi*, J. Sowerby, which could be recognized at once as being allied to *Schlotheimia Charmassei*, d'Orbigny, sp. On going into the matter in greater detail it was found that the suspicions of some Ammonite workers regarding the misinterpretation of the species by most previous authors were, indeed, well founded. Quenstedt,[1] for example, had stated that Wright, having found Sowerby's type very much disfigured by decomposition of pyrites, substituted for it a gigantic specimen of a diameter of 440 mm., "which, however, looks different again." Pompeckj[2] again stated that the gigantic specimen drawn by Wright, as well as his description defined the species in a not very precise manner, and that, therefore, it was not certain that the specimen agreed with Sowerby's original.

It will be shown in the following pages that whereas *Amaltheus Greenoughi* (Sowerby), Wright, had, by most recent writers, been regarded as an *Oxynoticeras*[3] from the *oxynotum* zone, Sowerby's form is a *Schlotheimia*, and appears to be restricted to the *Bucklandi* beds, or, more correctly, to the *rotiforme* subzone[4] only. The matter seemed of sufficient importance to be recorded without delay.

There are now in the Sowerby Collection in the British Museum two specimens bearing the original Sowerby label, "*Ammonites*

[1] F. A. v. Quenstedt, *Die Ammoniten des Schwäb. Jura*, vol. i, p. 297, 1885.

[2] J. F. Pompeckj, "Notes sur les Oxynoticeras, etc.": Comm. Serv. Geol. Port., vol. vi, fasc. 2, p. 264, 1906.

[3] Neumayr in 1875 ("Die Ammon. der Kreide, etc.": Zeitschr. Deutsch. Geol. Ges., vol. xxvii, p. 886) first put *A. Greenoughi*, Sow. (Hauer) into the genus *Amaltheus*, and in 1878 ("Über unvermittelt auftretende Cephalop.": Jahrb. k. k. Reichsanst., vol. xxviii, p. 61) he included it in the group *Fissilobati* of that genus, together with a heterogeneous mixture of other Ammonites. Wright, in 1882, followed Neumayr, but Tate & Blake (in *Yorkshire Lias*, 1876, p. 296) referred the form to the genus *Phylloceras*; and in H. B. Woodward (*Jurassic Rocks of Britain*, vol. iii, p. 336) both *Amaltheus* and *Phylloceras* are given. S. S. Buckman (in L. Richardson, *Geology of Cheltenham*, 1904, p. 212), on the other hand, assigned the form to the genus *Agassiceras* [*Agassizoceras*].

[4] i.e. Lower *Bucklandi* zone; see S. S. Buckman, *Yorkshire Type Ammonites*, vol. i, p. xvi, 1910.

Greenoughi, M.C. T. 132," as well as a very large specimen of a diameter of 520 mm., the history of which is unknown. Although the catalogue handed to the Museum with the collection records, in J. de C. Sowerby's handwriting, only one example of *A. Greenoughi*, it is probable that the Sowerby Collection originally included three specimens, namely: (A) the figured specimen (holotype) which, according to Wright,[1] is decomposed and cannot now be traced; (B) the smaller of the specimens afore-mentioned (B.M. Geol. Dept., No. C 17640); (C) a larger specimen of 440 mm. diameter (B.M., No. C 17641).

The smaller of these two paratypes, i.e. specimen B, best illustrates the species, and is, therefore, now taken as the lectotype (see Plate IV). It is suggested that Wright did not know of the existence of this specimen when he described the form. It measures about 230 mm. in diameter, but has two-fifths of the outer whorl missing and also the innermost whorls. The specimen consists of a cast in iron-pyrites filled loosely with calcite crystals in large scalenohedra. Its body-chamber portion, marked "Part of the large specimen which is in fragments", now measures only about one-quarter of a whorl, but, to judge by the umbilical junction preserved on the previous whorl, originally consisted of at least three-quarters of a whorl. On the accompanying Plate IV this body-chamber fragment is omitted, but it would reach from *a* (the end of the septate stage) to *b*. The complete Ammonite then measured some 320 mm. in diameter. This body-chamber portion consists of a bluish-grey limestone, weathering to a softer and lighter-coloured stone, typical of Somerset and especially the Bath–Keynsham district.

The specimen cannot be the entirely septate Ammonite figured by Sowerby,[2] for it is of quite a different appearance. Even if it had been entire and in good condition at the time of preparation of Sowerby's figure, the short distance of its conspicuous last suture[3] from the end of the costate stage would almost certainly have been correctly indicated by Sowerby. The dimensions agree, however, as the following figures show, testifying to the probable accuracy of Sowerby's delineation.

	Diameter.	Height.	Thickness.	Umbilicus.
Sowerby's figure .	113 mm.	47 per cent	? 24 per cent	21 per cent
Specimen B at .	140 ,,	48 ,,	? 26 ,,	21 ,,
,, at .	203 ,,	47 ,,	? 23 ,,	21 ,,

Now Wright states that the specimen he studied had a diameter of 440 mm. But this diameter agrees with the second specimen (C) of the Sowerby Collection, whereas the one that Wright[4] figured

[1] T. Wright, *Lias Ammonites* (Mon. Pal. Soc.), 1882, p. 384.

[2] *Mineral Conchology*, vol. ii, p. 71, pl. 132, 1816.

[3] This distance, in the large, comparable specimens, amounts to about one whole whorl, and it is probable, therefore, that Sowerby's figure is reduced to, perhaps, as much as one-third of the original diameter, especially since he states that specimens vary in size from 12 to 18 inches in diameter. The suture-line itself has the lateral saddle higher and larger than the external saddle, and is apparently of a *Schlotheimia* pattern. Only the last ones at about 200 mm. diameter are visible (at *a* in the figure), but they are, unfortunately, not clearly traceable.

[4] T. Wright, op. cit., pl. xliv.

(B.M. No. 82363) has a diameter of 520 mm. Wright does not mention that he had two specimens; but his figure evidently is a composite one, the obscure costæ of the outer whorl showing on the former specimen only, though in a less distinct manner. Moreover, whereas his figured specimen has the locality "Somerset" attached to it, Wright says that no locality was recorded, which again is the case with C, Sowerby's specimen of 440 mm. diameter. Wright thought that it probably came from Lyme Regis, "from the petrological character of the matrix in which it was embedded," but this is doubtful, as also is Morris's[1] mention of the species from Lyme thirty-nine years earlier, and the record of *A. Greenoughi* from the [*oxynotum* zone ? of the] neighbourhood of Cheltenham both by J. Buckman[2] and by S. S. Buckman.[3]

Sowerby's specimen C of 440 mm. diameter has the following dimensions:—

Height,	42	per cent of the diameter.	
Thickness,	? 24	,,	,,
Umbilicus,	29	,,	,,

On comparing these dimensions with those of the lectotype (B) it will be seen that, whereas the height of the whorl has diminished from 47 to 42 per cent, the umbilicus has widened considerably (from 21 to 29 per cent). It appears probable that this is the normal development of the form, i.e. that it is a case of latumbilication arising from excentric coiling. And specimen C, indeed, clearly exhibits this excentrumbilication, though not the specimen figured by Wright. The latter has at a diameter of 520 mm. the following dimensions:—

Height,	42	per cent of the diameter,	
Thickness,	? 24	,,	,,
Umbilicus,	30	,,	,,

whereas his (reduced) figure shows—

Height,	41	per cent of the diameter,		
Umbilicus,	31	,,	,,	(34 per cent in the text).

These dimensions agree well with those of the large specimen (C) mentioned above, and also show that Wright's delineation was fairly accurate so far as the dimensions are concerned, although in the absence of a sectional view the shading suggests thicker whorls and the obscure costæ on the body-chamber are too pronounced. Important differences appear, however, when we compare the costation of the inner whorls of these two large specimens with that of the lectotype. The latter has, counting backwards from the last rib at a diameter of about 145 mm., twenty and fifteen primary costæ respectively for these two whorls. They give rise to about two or three secondaries each, and these are continuous across the periphery at a diameter of 90 mm. when they weaken and finally, at 200 mm. diameter, almost entirely disappear.

[1] John Morris, *Catalogue of British Fossils*, 1843, p. 173.
[2] In Murchison, *Geology of Cheltenham*, 2nd issue, 1845, p. 89.
[3] In Richardson, *Geology of Cheltenham*, 1904, p. 212 (as *Agassiceras* [*Agassizoceras*] *Greenoughi*).

The inner whorls of the two larger specimens could not be exposed, and comparison therefore is difficult. But whereas Sowerby's specimen (C) has twenty-eight and nineteen costæ respectively on the two last wholly costate (inner) whorls, the specimen figured by Wright has twenty and sixteen respectively, again counting backwards from the last distinct rib shown in the umbilicus. The latter number is the same as in the lectotype; but Wright's specimen differs both from the latter and from the more closely costate specimen (C) in having more regularly (not excentrically) coiled inner whorls which are coarser and rounder. The outer whorl of Wright's specimen, on the other hand, is flatter and smooth.

Since neither of the large specimens therefore agrees with the lectotype, it seems advisable to refer to these forms only as "*Schlotheimia* spp. ex aff. *Greenoughi* (Sowerby)", until duplicate specimens enable us to study their inner whorls and to define their (possibly specific) differences from the lectotype more definitely. What Wright[1] says about the resemblance of the young to *Oxynoticeras guibalianum* (d'Orbigny) and the presence of a keel in specimens of from 6 to 8 inches in diameter is, of course, erroneous. Sowerby had stated that the "undulations are continued and rather strongest over the rounding back", and though in his figure that author did not give quite the correct course of the radial line, the above remark obviously did not point to connexion with *Oxynoticeras*. Wright here followed previous authors, especially von Hauer, whose *A. Greenoughi*,[2] like that figured by Parona,[3] has now been included in Fucini's *Oxynoticeras Haueri*.[4] Sowerby's Ammonite, unfortunately, has been misinterpreted by Continental writers since the time of von Buch. That author figured as *A. Greenoughii*[5] an Ammonite that Quenstedt[6] thought might be the same as *A. Tessonianus* of d'Orbigny from the iron-oolite δ (i.e. *witchellia* zone of the Inferior Oolite), and Giebel[7] mentions that Graf Münster records it from the Oxford Clay. Studer[8] has it from the Upper Lias (Toarcian), and Ooster's *A. Greenoughi*[9] again is, according to Hug,[10] an *Oxynoticeras* of *guibalianum* type. Dumortier[11] also probably misinterpreted the species when he recorded it from the *oxynotum* zone.

[1] T. Wright, *Lias Ammonites*, p. 385.

[2] F. v. Hauer, "Über die Cephalop. aus dem Lias der Nord-Östlichen Alpen": Denkschr. Akad. Wiss. Wien. Math.-Naturwiss. Klasse, vol. xi, p. 46, pl. xii, figs. 2–4, 1856.

[3] C. F. Parona, "Ammon. Lias infer. Saltrio": Mem. Soc. Pal. Suisse, vol. xxiii, p. 18, pl. i, fig. 2, 1896.

[4] A. Fucini, "Cefal. Lias. del Mte. di Cetona," part i: Pal. Ital., vol. vii, pp. 8–9, 1901.

[5] L. v. Buch, *Explication de trois Planches d'Ammonites*, 1830, pl. i, figs. 2*a*–*c*.

[6] F. A. v. Quenstedt, *Handbuch der Petrefaktenkunde*, 1852, p. 364.

[7] C. G. Giebel, *Fauna der Vorwelt*, vol. iii, p. 554, 1852.

[8] B. Studer, *Geologie der Schweiz*, vol. ii, p. 36, 1853.

[9] W.-A. Ooster, *Cat. Ceph. Foss.*, vol. vi, p. 45, pl. xvi, figs. 1, 2, 1863.

[10] O. Hug, "Beitr. Kenntn. Lias & Dogger Amm. Freiburger Alpen," II: Abh. Soc. Pal. Suisse, vol. xxvi, p. 6, 1899.

[11] E. Dumortier, *Etudes Paléont. Dépots Jurass. Bassin du Rhone*," vol. ii, p. 148, 1867.

De la Beche's[1] mention of the form (he alters the name to *A. Greenovii*) from the Lower Oolite of Bayeux, and a diagrammatic figure of it published by T. Brown,[2] were equally unfortunate, and Blake[3] apparently confused Sowerby's Ammonite with *oxynoticerates* of *Salisburgense* type, since he records two specimens of it from the *oxynotum* zone of Yorkshire, though he says that one specimen, doubtfully identified with it, occurred in the *Bucklandi* beds near Redcar. But it is chiefly on Wright's authority that more recent writers, including Hyatt[4] and Pompeckj,[5] put *A. Greenoughi* with or near *Oxynoticeras guibalianum*, d'Orbigny, sp., and into the *oxynotum* zone.[6] Pompeckj, who, as has already been pointed out, is not satisfied about Wright's interpretation of the species, mentions that *O. Greenoughi* is also quoted from the *Bucklandi* zone of England, "or more correctly the subzone of *Ariet. semicostatum*=subzone of *Ariet. geometricus* or of *Pentacrinus tuberculatus*." In fact, in Somerset (at Bath, Keynsham, etc.), whence probably all the known specimens came and whence the species is recorded by Lonsdale[7] and Morris,[8] it is associated with *Vermiceras* and *Coroniceras*, and therefore belongs to the *rotiforme* or Lower *Bucklandi* zone and not to the *geometricum* or Upper *Bucklandi* zone.

With regard to the other forms of *Schlotheimia* that occur in the *Bucklandi* zone, the dimensions are given below of three large examples quoted by Pompeckj[9]—

	Diameter. mm.	Height. per cent	Thickness. per cent	Umbilicus. per cent
Schlotheimia Charmassei, d'Orbigny, Pompeckj (= *A. angulatus compressus*, Quenstedt, ii, 2, 1883) .	149	46	24	24
Schl. intermedia, Pompeckj (= *A. angulatus intermedius gigas*, Quenst., pl. iv, fig. 1, 1883) .	600	38	18	32
Schl. d'Orbignyana (Hyatt), Pompeckj (= *A. angulatus compressus gigas*, Quenst., pl. iv, fig. 2, 1883) . .	420	48	18	21

[1] H. de la Beche, "On the Geology of Part of France": Trans. Geol. Soc., ser. II, vol. i, p. 80, 1822.

[2] T. Brown, *Illus. Foss. Conch.*, etc., 1849, p. 12, pl. ix, figs. 7, 8.

[3] In R. Tate & J. F. Blake, *Yorkshire Lias*, 1876, p. 296.

[4] A. Hyatt, "Genesis of the Arietidæ": Smithsonian Contributions to Knowledge, 1889, p. 218.

[5] J. F. Pompeckj, op. cit., p. 264.

[6] E. Böse, however, had pointed out in 1894 ("Fleckenmergel": Zeitschr. Deutsch. Geol. Ges., vol. xlvi, p. 747) that *A. guibalianus*, d'Orbigny, sp., and *A. Greenoughi*, J. Sowerby, could not be united as they were by Hyatt, since the ribbing was quite different "if one could judge at all from the bad original figure". We have seen already that Sowerby's figure was for his time very good, but authors, unfortunately, do not seem to have consulted the text. On p. 70 Sowerby also made the important remark (which apparently had quite escaped attention) that *A. Conybeari* and *A. Greenoughi* were generally companions in the same stratum, and were occasionally impressed with each other's type.

[7] W. Lonsdale, *Trans. Geol. Soc.*, ser. II, vol. iii, p. 272, 1832.

[8] J. Morris, *Cat. Brit. Foss.*, 1843, p. 173.

[9] J. F. Pompeckj, *Beiträge z. e. Revision der Ammon. Schwäb. Jura*, pt. i, pp. 81–3, 1893.

The first is clearly of the type of *Schlotheimia Greenoughi*, though just a trifle too evolute, since its umbilicus measures 24 per cent, instead of 21 per cent at the same diameter. It is also too densely costate, as is d'Orbigny's original figure of *A. Charmassei*[1] (especially on the inner whorls) and Wright's '*Ægoceras*' *Charmassei*.[2] The latter also has a sulcate periphery to a larger diameter than the others, and Dumortier's *A. Charmassei*[3] is distinguished by its flexicostation, as well as by the closeness of its ornament.

S. intermedia, Pompeckj, greatly resembles the two large forms that are here considered to be allied to *S. Greenoughi*, but may be a little thinner, though the exact thickness of the latter cannot be determined owing to the corrosion of one side of the specimens. The costation differs in being a little too close.

S. d'Orbignyana (Hyatt), Pompeckj, has at a diameter of 420 mm. the dimensions of the considerably smaller example of *S. Greenoughi*, i.e. it remains involute; but its costation also is too close and the periphery too sharp.

Finally, as an illustration of the excentric coiling of some forms of *Schlotheimia*, it may be mentioned that in *S. depressa* (Wähner), Pompeckj[4] (= *A. angulatus thalassicus*, Quenstedt, 1883, pl. ii, fig. 4 only), the inclusion decreases from 41 to 28 per cent in less than a whorl, whereas in *S. thalassica*, Quenstedt, sp. (= *A. angulatus thalassicus*, Quenstedt, 1883, pl. ii, fig. 5), the umbilicus, owing to the rapid increase in height of the last whorl, decreases from 50 to 37 per cent at diameters of 32 and 100 mm. respectively.

In conclusion, I should like to express my best thanks to Dr. A. Smith Woodward, through whose kind offices I was permitted to work on the rich store of Ammonites in the British Museum, and to Mr. G. C. Crick for placing his extensive knowledge of the collection at my disposal.

II.—Radio-activity and the Earth's Thermal History.

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

PART II.

Radio-activity and the Earth as a Cooling Body.[5]

7. Other Sources of Terrestrial Heat.

So far, the source of the heat lost from the earth has been assigned only to the disintegration of the radio-active elements. Besides this, heat is liberated near the surface by the processes of weathering. The decomposition of one gram of average rock is accompanied by the generation of about 120 calories. Owing to its extreme slowness, this

[1] A. d'Orbigny, "Paléont. Franç. Terr. Jurass. Ceph.," pl. xci, figs. 3, 4, *non* 1–2, *nec* pl. xcii (see S. S. Buckman, "Some Lias Amm.": Proc. Cotteswold Club, vol. xv, pt. iii, p. 239, 1906).

[2] T. Wright, op. cit., 1880, pl. xx.

[3] E. Dumortier, op. cit., 1867, p. 29, pl. xvii, fig. 1.

[4] See J. F. Pompeckj, op. cit., p. 78, and F. Wähner, "Beitr. Kenntn. tieferen Zonen d. Unt. Lias i. d. Nö. Alpen," part iii: Beitr. Pal. Österr.-Ung., vol. iv, p. 164, 1886.

[5] Part I, "The Concentration of the Radio-active Elements in the Earth's Crust," appeared in the February Number, pp. 60–71.

source of heat generation is of practically no importance except locally, where for a time it may succeed in appreciably steepening the temperature gradient. The heat liberated by weathering is probably balanced by the absorption of heat at greater depths, which is involved in the processes of metamorphism. Of much greater importance is the question whether the earth can still be regarded as possessing an ancient heritage of heat dependent on its origin.

According to the Laplacian hypothesis the earth began as a hot gaseous spheroid, and its subsequent history has been largely dependent on the gradual cooling from that initial state. The Meteoric hypothesis of Lockyer leads to an earth having a similar thermal history. In each of these cases original heat is regarded as by far the most important source of the earth's thermal energy. Recently, however, both of these hypotheses have been discredited on dynamical and other grounds, and Professor Chamberlin has introduced his Planetesimal hypothesis as an alternative which successfully overcomes the difficulties encountered by the older views. According to Chamberlin[1] (writing in 1905) there are four main sources of heat arising from the mode of origin postulated by the Planetesimal hypothesis. (1) The original earth nucleus about which the planetesimals gathered may have been hot, the heat being partly original, partly the result of condensation. (2) By the infalling of planetesimals heat would be produced. If the infalling were sufficiently rapid, the heat newly generated would be retained and the surface might be kept in a state of fusion. It is considered, however, by Chamberlin that in the later stages the rate of accretion became so slow that most of the heat generated by impact was radiated away. (3) The chief source of heat is assigned to mechanical compression in the interior of the growing earth. (4) Another effect of compression would be a molecular re-arrangement by which denser compounds would be produced. It is thought probable that this re-combination would be attended by the liberation of thermal energy.

Dr. A. C. Lunn[2] has discussed mathematically the thermal condition of the earth on the basis of the Planetesimal hypothesis. He takes into account only heat derived from gravitational energy, remarking that the heat obtained from other sources might be relatively important, and that if it were of sufficient magnitude it would completely alter the thermal process.[3] According to the assumptions made, which are admitted to be uncertain, Lunn finds the temperature gradient near the surface to be only 330° C. in 200 miles (0·00001° C. per cm.). The actual present gradient is about 0·00032° C. per cm. Such a result, obtained before the geological significance of radio-activity was realized, appears to be in complete harmony with the fact that radio-activity seems to leave little room for any appreciable temperature gradient due to an original store of heat. Writing in 1911 Chamberlin pointed out this co-operation of planetesimal and radio-active agencies,[4] and he also indicated the

[1] Chamberlin & Salisbury, *Text Book of Geology*, vol. ii, p. 100, 1906.
[2] Carnegie Inst., Washington, Pub. No. 107, 1909, p. 169.
[3] Lunn, loc. cit., p. 230.
[4] *Journ. Geol.*, p. 673, 1911.

additional difficulty of maintaining belief in a molten earth which the new source of energy had introduced. This difficulty, however, which has been very generally realized, is really one of time. If the earth has cooled down at all, the effect of radio-activity will have been to slow down the rate of secular cooling. What the presence of radio-activity does prove in such a case is that the earth must be very much older than the twenty or forty million years allowed by Kelvin for the process of cooling from a molten state to present conditions.

8. The Age of the Earth.

A very simple method will serve to show approximately the effect of radio-activity on the normal rate of cooling, and on the age of the earth to be deduced from it. The temperature gradient $d\theta/dx$ is inversely proportional to the square root of the time of cooling, t, which is, on this view, the age of the earth (i.e. $d\theta/dx \propto 1/\sqrt{t}$). If five-sixths of the present temperature gradient be due to radio-activity, then only one-sixth can be attributed to cooling. The above formula indicates that if the gradient $d\theta/dx$ is reduced to one-sixth, then the time of cooling, t, must be thirty-six times as great. The effect of radio-activity is thus to raise Kelvin's limits from twenty and forty million years to 720 and 1,440 million years. A more rigid mathematical treatment shows that radio-activity is even more powerful in slowing down the rate of cooling than appears from these figures, and it becomes clear that if ever the earth was molten at the surface it could not, with the existing distribution of the radio-active elements, have cooled down to its present state in less than 1,600 million years.

It is therefore of interest to know that an independent method of determining geological time—though also based on radio-activity—gives results which for the oldest rocks closely approach this figure. Every uranium-bearing mineral is like a clock ticking out its age in molecules of helium and lead. Helium is generated also during the decay of thorium, but the end-product of thorium is still unrecognized. It cannot be an equivalent of lead, since in thorium minerals this element does not accumulate in geological time.[1] In uranium-bearing minerals, however, lead does accumulate, and the rate of its production is accurately known.[2] In any primary mineral the amount of uranium engaged in the generation of lead, and the amount of lead which has accumulated, factors which can generally be estimated by analysis, suffice to determine the age of the mineral. The geological time scale, as far as at present determined, is given on p. 105.

The oldest rocks in this table, which appear to be the gneissose granites of Mozambique, are probably not more ancient than the oldest rocks in any of the great Archæan areas. In Fenno-Scandia and North America there are rocks of much greater geological antiquity than those for which ages are here given. There is, naturally, great difficulty in obtaining suitable minerals for analysis.

[1] Holmes & Lawson, *Phil. Mag.*, vol. xxviii, p. 823, 1914.

[2] For a full discussion of this method of estimating the age of minerals, see Proc. Roy. Soc., A, vol. lxxxv, p. 248, 1911, and *The Age of the Earth*, ch. x, 1913.

When such material is collected from the oldest rocks of the Archæan shields, it is probable that the ages will be found to approximate to 1500–1600 million years.

For the purposes of this paper the period which has elapsed since the crystallization of the oldest gneissose granites or orthogneisses, a period which may be referred to as the age of the earth, will be taken, independently of thermal considerations, as 1,600 million years. With such an extended period in which to cool, an earth originally molten at or near the surface would now have a temperature gradient so low that it could easily be hidden under the much more imposing gradient due to radio-thermal energy. We must, therefore, examine afresh the evidence for and against an earth originally molten at or near the surface.

Geological Period.	*Age in millions of years.*
Carboniferous, U.S.A.	340
Devonian, Norway	370
Silurian or Ordovician, U.S.A.	430
Pre-Cambrian :—	
Galle pegmatites, Ceylon	800
Unfoliated granites, G. E. Africa	800
Moss complex, Norway	1,000
Ser-Archæan, Sweden	1,100
Arendal complex, Norway	1,250
Algoman (?), Canada	1,200
Intrusive granites, Madagascar	1,250
Intrusive granites, Mozambique	1,100
Gneissose-granites, Mozambique	1,500
Thorianite, Ceylon	1,600 (?)

9. The Thermal Problem of the Original Crust.

As already suggested, Chamberlin holds that the infalling of planetesimals during the later stages of the earth's growth was so comparatively slow that the heat generated was readily radiated away. Indeed, he believes that oceans first became possible at a stage when the earth was much smaller than now, and thus denudation and deposition, both mechanical and chemical, began while the earth was still growing by the capture of planetesimals. Daly raises the objection [1] that if this view is correct the ocean ought to be more salt than it actually is. This criticism is undoubtedly well founded, for the difficulty of reconciling the conflicting estimates of geological time based on salinity and radio-active data respectively becomes still worse if the ocean is considered to be older than the oldest known rocks. Dr. Evans has suggested to me that if the composition of the planetesimals which completed the growth of the earth was at all similar to that of meteorites, then the earliest known sediments, which must have been produced partly from fresh planetesimal material and partly from volcanic rocks and pre-existing sediments, ought to betray the peculiar nature of their source by some peculiarity in their chemical composition. In particular, it is reasonable to expect that they would contain determinable quantities of nickel. This does not seem to be the case, and in fact the earliest

[1] *Igneous Rocks and their Origin*, p. 115, 1914.

sediments do not differ chemically in any essential respect from those of later date. It might, however, be worth while to examine the older sediments or their metamorphic equivalents for a possible nickel content. Such rocks contain manganese, although in meteorites, even in the stony varieties, nickel is always much more abundant than manganese.

The view that the external shell of the earth has not been in a general molten condition depends on the assumption that radiation from the surface was able to keep pace with the heat generated by impact, together with the amount brought to the surface by conduction from the interior and the still greater amount carried by the extrusion of molten tongues of the lighter and, with the aid of volatile fluxes, more fusible materials. As Daly has pointed out,[1] it is very doubtful whether this assumption can be justified.

Another factor suggested by Dr. Evans which must be taken into consideration is the thermal blanketing that would result as soon as an atmosphere was generated. For the primitive atmosphere would be exceedingly rich in carbon-dioxide and water vapour, athermanous substances that would very efficiently absorb thermal radiations and conserve the growing supply of heat within. It is impossible to discuss quantitatively the relation between heat generation and radiation in so complex a system, and it can only be said that the assumption of a solid crust throughout the later stages of growth has to overcome a number of difficulties which would not otherwise be so serious.

There can be no doubt that the mechanism by which granitic and basaltic magmas were differentiated from average planetesimal material and arranged according to their densities would work very much more quickly and effectively if the earth were molten near the surface during the whole period of growth, than if the temperature of fusion were not reached until the freshly fallen planetesimals had been buried to a considerable depth. There is, in fact, clear evidence that fusion temperatures did in the early history of the earth come very near the surface. The great abundance of Archæan granites and orthogneisses throughout the continents proves a widespread molten condition at no very great depth. It may be objected that where the relations between the oldest granites and the oldest sediments are indeterminable, the former are always intrusive. This is, however, just what would be expected, for sedimentation implies submergence, and the rocks constituting the underlying platform of deposition must therefore have been lowered to depths where considerably higher temperatures would be reached. If the temperature gradient were high in these early days, the rise of temperature might easily reach the point of refusion. Moreover, an additional effect of sedimentation would be to cover the underlying platform with a radio-active layer which, as Joly has shown,[2] would substantially raise the basal temperature still further. Thus, granting a sufficiently high temperature gradient in these early times, there is no difficulty in understanding the irruptive contacts of the most ancient igneous

[1] *Igneous Rocks and their Origin*, p. 157, 1914.
[2] *Radio-activity and Geology*, p. 102, 1909.

rocks. Chamberlin believes that the temperature gradient in the outer part of the earth was such as to preserve "equilibrium between solidity and liquefaction according to the conditions present at each depth".[1] The oldest Archæan rocks imply that at the time of their formation the equilibrium between solidity and liquefaction began at no great depth from the surface.

A further criticism made by Daly against the view of a solid exterior during the later stages of growth is based on a comparison of the average densities of the earth and the outer planets and sun. The low densities of the outer planets may be due to high temperature or to the absence of heavy elements. As in the case of the sun, the interpretation of astrophysics is that the temperature is high. If the larger planets are still in a condition of high temperature it seems likely that the earth has passed through an essentially similar stage.

The contraction of the earth evidenced by the phenomena of mountain building is not invoked in this discussion because there are sources of contraction other than cooling, notably mechanical compression, chemical readjustment, and physical change of state. If cooling were admitted as the chief cause of contraction, then the universality of orthogneisses among the earliest igneous rocks and of cleavage, foliation, crumpling, and distortion among the earliest sediments, and the gradual restriction of these features in later geological time to narrow belts on the earth's surface, points at once to more rapid cooling in the outer part of the crust during the earlier of the Pre-Cambrian periods, and therefore to a higher temperature from which to cool. It is doubtful, however, whether this argument is valid. It is certainly true of contraction, but not necessarily true of cooling.

Summing up we may conclude that considerations based on—

(1) the existing salinity of the ocean;

(2) the absence of ancient sediments or schists with significant peculiarities of composition;

(3) the possibility of heat generation being greater than radiation during the later stages of the earth's growth;

(4) the probability of a strongly athermanous primitive atmosphere;

(5) the density stratification of the earth, particularly in its outer shell;

(6) the universality of plutonic igneous rocks and their metamorphic equivalents at no great depth in early Archæan times;

(7) the probable high temperatures of the larger sister planets,

all point to the improbability of a solid exterior during the earth's later stages of growth, while conversely, they all favour the probability that magmatic temperatures existed at or immediately below the surface throughout the period of growth.

10. Mathematical Treatment.

The effect of radio-activity on earth temperatures and the rate of cooling has been ably discussed mathematically by Messrs. L. R. Ingersoll and O. J. Zobel, of the University of Wisconsin, in their recent book on the Mathematical Theory of Heat Conduction (Ginn & Co., 1913). They assume that only a fraction, $1/n$, of the total annual

[1] *Journ. Geol.*, p. 686, 1911.

loss of heat from the earth is supplied from radio-thermal energy, and that the distribution of the radio-elements falls off exponentially in depth. Their final equation (No. 85, p. 95) expresses θ, the temperature at any depth x, and at any time t, in terms of the following data:—

S, the initial temperature at, or just below, the surface.
m, the initial temperature gradient.
k, the thermal conductivity of average rock.
$h^2 = k/c\rho$, the diffusivity of average rock.
c, the specific heat of average rock.
ρ, the density of average rock.
A, the heat production of unit volume of average rock per second.
a, the decrease of heat generation per unit distance in depth.

For the details of the equation and the treatment leading up to it the reader is referred to the original work. Mr. Zobel has very kindly differentiated this equation for me, and much of the mathematical treatment which follows below is due to his help, for which I wish here to express my gratitude. Differentiating equation 85, the temperature gradient for any time t, and at any depth x, is obtained. The temperature gradient $d\theta/dx$ is actually measured at the present time at the surface, so that $x=0$. The equation then becomes

$$d\theta/dx = m + \frac{S}{h\sqrt{\pi t}} + \frac{A}{ak}\left[1 - e^{a^2h^2t} \cdot \frac{2}{\sqrt{\pi}}\int_{ah\sqrt{t}}^{\infty} e^{-\gamma^2}\,\delta\gamma\right]$$

For large values of $ah\sqrt{t}$, the equation may be expressed more simply as

$$d\theta/dx = m + \frac{S}{h\sqrt{\pi t}} + \frac{A}{ak}\left[1 - \frac{1}{ah\sqrt{\pi t}}\right] \qquad (10)$$

The unknowns in this equation are m, S, and a, and obviously two of them must be assumed to be known. It is highly improbable that the initial temperature of the earth was uniform throughout. The work of Barus shows that the temperature of fusion increases with pressure and therefore with depth. Although this law may not hold to any great depth, yet the temperature must also increase with depth as a result of compression. Originally, then, the temperature θ at any depth x would be $\theta = mx + S$.

It is assumed here that:

$$m = 0{\cdot}00005^\circ \text{ C. per cm.}; \quad S = 1{,}000^\circ \text{ C.}$$

The known factors in equation 10 are [1]—

$d\theta/dx = 0{\cdot}00038^\circ$ C. per cm.
$t = 1{,}600$ million years $= 5{\cdot}05 \times 10^{16}$ seconds.
$A = 63{\cdot}9 \times 10^{-14}$ calories per second per c.c. of rock.
$k = 0{\cdot}005^\circ$ C. per cm.
$\rho = 2{\cdot}8$.
$C = 0{\cdot}25$.
$h^2 = k/c\rho = 0{\cdot}0071$.
$h = 0{\cdot}084$.

Equation 10 may now be solved for a, which is found to be 4×10^{-7}.

[1] See Part I, GEOL. MAG., Dec. VI, Vol. II, p. 70, 1915.

The first two terms of equation 10 are those which would obtain if no radio-thermal energy were present[1] (i.e. $x = 0$ and $A = 0$). They, therefore, represent the contribution to the temperature gradient furnished by the earth's original thermal condition, and the third term represents that portion of the gradient which is due to radio-activity. The total heat q which issues from unit area of the earth's surface is obtained by multiplying equation 10 throughout by k, since $q = k\, d\theta/\theta x$. We may therefore write—

Total heat flow per unit area due to initial thermal state

$$= mk + Sk/h\sqrt{\pi t}.$$

Total heat flow per unit area due to radio-activity, R,

$$= \frac{A}{a}\left[1 - \frac{1}{ah\sqrt{\pi t}}\right]$$

$$\text{or, } R = q - \left[mk + Sk/h\sqrt{\pi t}\right] \qquad (11)$$

In Part I (p. 64) it was assumed that $R = q = A/a$, which would be strictly true only after an infinite time. Here it is assumed that $1/n$ of the earth's heat is due to radio-activity, i.e. $R = q/n$. Hence from equation 11 we have

$$q/n = q - \left[mk + Sk/h\sqrt{\pi t}\right]$$

$$\text{or, since } q = k\, d\theta/dx$$

$$(d\theta/dx)/n = d\theta/dx - \left[m + S/h\sqrt{\pi t}\right].$$

Here the only unknown is n, which is given by

$$n = \frac{d\theta/dx}{d\theta/dx - m - S/h\sqrt{\pi t}} \qquad (12)$$

$$= 4/3.$$

This result could also be obtained as follows: without radio-activity the temperature gradient at the surface after 1,600 million years of cooling would be

$$d\theta/dx = m + S/h\sqrt{\pi t}$$
$$= 0{\cdot}00005 + 0{\cdot}00003$$
$$= 0{\cdot}00008^\circ \text{ C. per cm.}$$

But the actual gradient is 0·00032° C., so that three-fourths of the total present heat flow is due to radio-activity.

The above discussion clearly proves that the earth could have cooled from a state in which it was molten at the surface to its present condition (as implied by the temperature gradient at the surface) even if three-fourths of the heat flow be due to radio-activity. This interesting conclusion must, however, be tested further by reference to volcanic temperatures. If the assumptions made bear a close relation to the actual conditions, they must lead to temperatures in depth in keeping with the facts of vulcanism.

11. Bearing on the Age of the Earth.

It is interesting to notice that in the absence of radio-thermal energy the age of the earth given by the data used in this paper would be twenty-two million years, the equation

$$t = 1\Big/\frac{h^2\pi}{S^2}\left(\frac{d\theta}{dx} - m\right)^2$$

being derived from the non-radio-active part of equation 10.

[1] See equation 61, Ingersoll & Zobel, loc. cit., p. 89.

This is practically the same as the result ultimately arrived at by Kelvin (twenty to forty million years, and probably nearer twenty than forty). Ingersoll & Zobel discuss a case in which one-fourth of the earth's heat is due to radio-activity, and show that the age is then to be doubled. If it be assumed that on the average three-fourths of the heat is due to radio-activity, then the age is raised to 1,600 million years, as shown by equation 12. It should be noticed, however, that the mathematical treatment does not take into consideration the slow decrease of the radio-active generation of heat with time. For example, 400 million years after the consolidation of the crust, the gradient due to radio-activity would be about 15 per cent higher than now, and at the time of consolidation the gradient would be about 20 per cent greater than now. It thus happens that, actually, the effect of radio-activity has been to retard normal cooling in the early periods of the earth's history more effectively than the mathematical treatment would suggest. Taking this into account, it can be shown that on the average the rate of cooling has been retarded about 10 per cent more than if the heat generation due to radio-activity were independent of time. Thus, the age of the earth as measured from the consolidation of the crust, if that event ever took place, would be 1,750 million years instead of 1,600 million years, or alternately, if 1,600 million years be adopted as the maximum, the heat flow from radio-activity must be slightly less than three-fourths of the whole, say about 27/40.

If the proportion of heat flow due to radio-activity is assumed to be higher than this, the age of the earth increases with great rapidity, and we are driven to choose between two alternatives—either

(*a*) that the age of the earth is much greater than 1,600 million years, or

(*b*) that the earth has never possessed a molten or even a nearly molten crust.

(*a*) cannot be readily granted, and therefore the practical alternatives lie between

(*b*) with more radio-thermal energy than is necessary to supply three-fourths of the total heat loss, and

(*c*) the conception of a cooling earth which originally had a molten crust and in which radio-activity supplies three-fourths, or nearly three-fourths of the present heat loss.

12. Deep-seated Temperatures.

The temperature θ at any depth x, and at any time t, is given by Ingersoll & Zobel's equation 85. Theoretically, the "steady state" in which all the heat from radio-active sources passes to the surface is arrived at only after an infinite time, and equation 85 then reduces to

$$\theta = mx + A/a^2k\left[1 - e^{-ax}\right].$$

Practically, however, the time t, 1,600 million years, is sufficiently long for the steady state to be assumed without appreciable error, and the temperature at any depth may thus be regarded as made up of two components, one, θ'', due to the initial thermal condition of the earth, and the other, θ', due to radio-active disintegration. From Ingersoll & Zobel's equation 60 (p. 89) we find—

$$\theta'' = mx + S \cdot \frac{2}{\sqrt{\pi}} \int_0^{\frac{x}{2h\sqrt{t}}} e^{-\beta^2} d\beta \qquad (13)$$

The evaluation of the "probability integral" attached to S can be obtained for different values of $x/2h\sqrt{t}$ $(=0{\cdot}00263x)$ from a table on p. 166 of Ingersoll & Zobel's book. The equation for the other component θ' has already been given in Part I, p. 69, as equation (9):

$$\theta' = A/a^2k\left[1-e^{-ax}\right] \qquad (9)$$

From 13 and 9 the total temperature $\theta = \theta' + \theta''$, at any depth x, can be calculated. The results for various depths are computed in Table V. It should be noticed that A/a^2k, the maximum possible temperature due to radio-activity, is 800° C.

TABLE IV.

Depth.	Equation 13.				Equation 9.			Total Temperature.
x in kms.	mx° C.	Probability, integral, p	Sp. (°C.)	θ'' (°C.)	e^{-ax}	$1-e^{-ax}$	θ'(°C.)	$\theta=\theta'+\theta''$
10	50	0·029	29	79	0·6704	0·6296	264	343° C.
20	100	0·059	59	159	0·4493	0·5507	441	600° C.
30	150	0·090	90	240	0·3011	0·6989	560	800° C.
40	200	0·118	118	318	0·2018	0·7982	640	958° C.
50	250	0·146	146	396	0·1353	0·8647	692	1088° C.
60	300	0·179	179	479	0·0907	0·9093	727	1206° C.
70	350	0·205	205	555	0·0608	0·9392	752	1307° C.
80	400	0·234	234	634	0·0408	0·9592	768	1402° C.
90	450	0·263	263	713	0·0273	0·9727	778	1491° C.
100	500	0·290	290	790	0·0183	0·9817	785	1575° C.

These results are highly satisfactory. In Part I, p. 70, assuming all the earth's heat to be due to radio-activity, it was shown that at a depth of 50 km. (31 miles) the most probable average temperature would be about 1100° C. Now, assuming that, in spite of radio-activity, the earth's crust has cooled down from an initial molten state, we find the temperature at a depth of 50 km. to be 1088° C. Moreover, in this case, the temperature continues to rise as the depth increases, so that, for example, at 100 kilometres the temperature is 1575° C. If all the earth's heat is due to radio-activity the maximum possible temperature is not likely to be more than 1200° C. It therefore appears that the assumption of a cooling earth leads to results more in keeping with the thermal necessities of igneous activity than does the assumption that the earth is in thermal equilibrium, its heat being maintained wholly by radio-thermal energy. It cannot be argued from this that the earth's crust *has* been molten, but it may be safely concluded that if other geological evidence points to, or requires, an initial molten crust, then there is nothing in the distribution of the radio-active elements to forbid belief in such a hypothesis.

13. Conclusions of Part II.

1. The effect of the generation of radio-thermal energy in the earth's crust is to slow down the normal rate of cooling, and it is shown that if the earth had originally a temperature of 1000° C., at, or just below the surface, the effect of radio-activity sufficient to maintain nearly three-fourths of the present flow of heat would be to increase the period of cooling from twenty-two million years to 1,600 million years.

2. The method of estimating geological time by lead-uranium ratios in radio-active minerals indicates that the oldest igneous rocks of the earth's crust have an age of about 1,500 million years.

3. Geological and other evidence points favourably to the traditional view that the earth's crust was initially in a molten state.

4. If the earth has cooled down from such a state to its present thermal condition, nearly three-fourths of the present heat output must be supplied by radio-activity.

5. Volcanic temperatures can be more satisfactorily obtained in depth on this view (4) than if the whole of the present temperature gradient is maintained by radio-activity (Part I).

6. There is nothing in the distribution of the radio-active elements either superficially or in depth to forbid belief in an earth which began with a molten surface, and which has gradually cooled down to its present condition.

Finally, I wish to express my thanks to Dr. Evans for valuable suggestions and salutary criticisms offered during many discussions on the subject-matter of this paper.

III.—Some Palæozoic Fossils referred to the Cirripedia.

By Thomas H. Withers, F.G.S.

SCATTERED throughout the Palæozoic rocks there are frequently found certain fossils, in most cases represented by single detached plates, which have been ascribed by various authors to the sub-class Cirripedia. Thus we have fossils described under the names *Balanus*, *Cirripodites*, *Lepidocoleus*, *Plumulites*, *Pollicipes*, *Protobalanus*, *Scalpellum*, *Stenotheca*, *Strobilepas*, and *Turrilepas*, but in the case of *Balanus*, *Pollicipes*, and *Scalpellum*, the reference to those recent genera is quite unsupported by the structure of the fossils.

While the Cirripede nature of some of these fossils appears to be undoubted, others as certainly are not Cirripedes, and for the remainder it would seem that, except for the similarity in ornament to the valves of Cirripedes, the main reason for such reference is the great difficulty in referring them to any other class of animals.

It is only occasionally that the plates of these forms are found in position so that we can gain some idea of what the complete shell was like, and although more or less complete specimens have been found of most of them, in no case is it possible to learn the precise relationship of the animal to the shell.

These brief notes are published in order to clear the ground for a more detailed study of some of the above-mentioned forms. I wish especially to point out that the occurrence in Palæozoic times of the essentially recent genera *Pollicipes* and *Scalpellum* is still unproved. In a paper now in course of preparation I propose to deal in more detail with the structure of *Turrilepas*, *Plumulites*, and *Lepidocoleus*.

BALANUS.

Under the name *Balanus carbonarius*, Petzholdt (*De Balano et Calamosyringe, Additamenta ad Saxoniæ Palæologiam duo*, 8vo, *Dresdæ* and *Lipsiæ*, 1841, p. 5, pl. i; "Über Balanus carbonaria," Neues Jahrb., p. 403, pl. iv, 1842) has described from the Carboniferous rocks near Dresden, Saxony, a group of fossils which, from the description and figure, it is impossible to accept as belonging to the genus *Balanus* or even to the Cirripedia at all. Darwin (Pal. Soc. Monogr. Foss. Lepadidæ, 1851, p. 5)[1] has already pointed out that, "as neither the operculum, the structure of the shell, the number of the valves, nor their manner of growth, can be made out or are described, the evidence appears quite insufficient to admit the existence of this genus at so immensely a remote epoch." Until further evidence is forthcoming we are unable to admit the Cirripede nature of this fossil.

PROTOBALANUS, R. P. Whitfield, and PALÆOCREUSIA, J. M. Clarke.

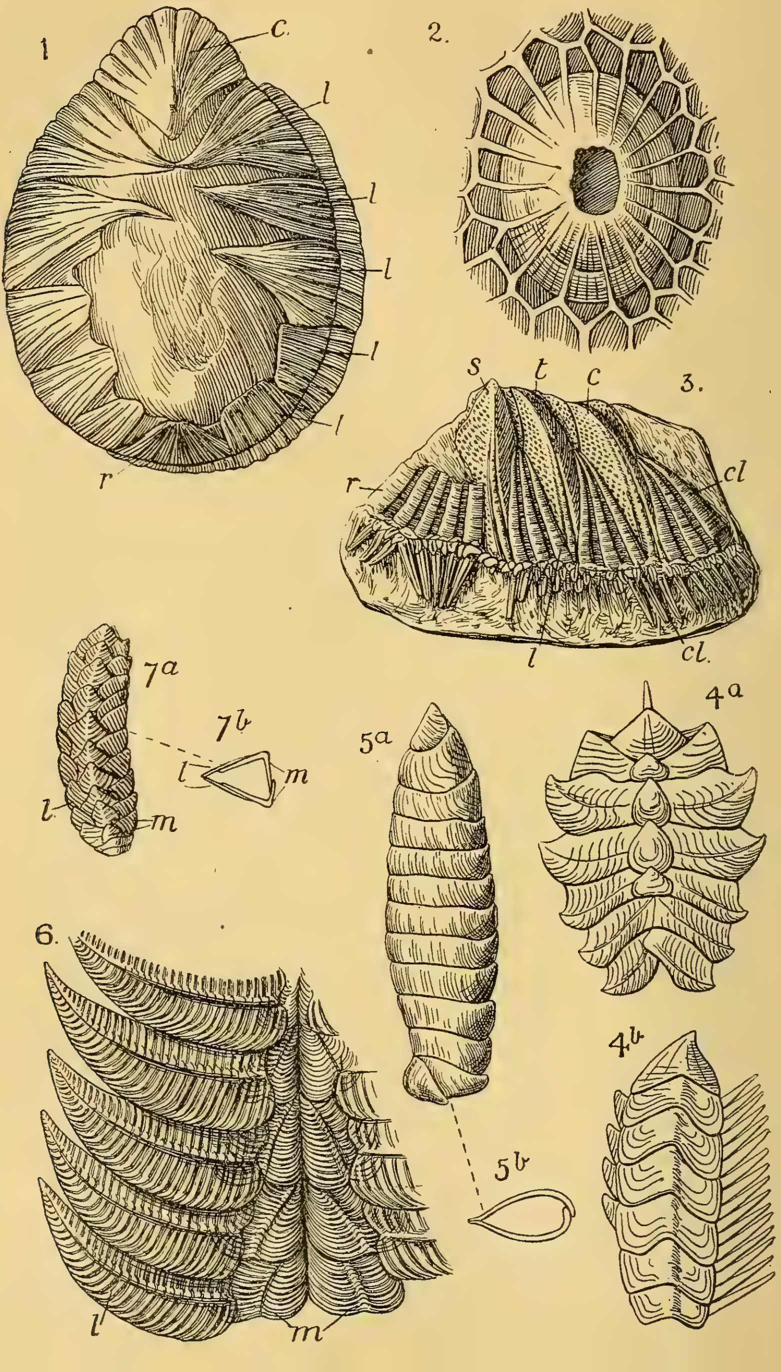
Both these forms appear to be Cirripedes and were founded on single specimens referred to the Balanidæ under the name *Protobalanus hamiltonensis*,[2] R. P. Whitfield, from the Middle Devonian, Hamilton Group (Marcellus shales) of Avon, Genessee Co., N.Y., and *Palæocreusia devonica*,[3] J. M. Clarke, from the Middle Devonian, Corniferous Limestone of Le Roy, Genessee Co., N.Y.

Protobalanus hamiltonensis (Fig. 1, p. 114) is represented by a small depressed-convex shell, ovate in general outline, narrowing towards the carinal end, and composed of twelve peripheral plates. There is a semicircular carina elevated above the other plates, a short rostrum, and five pairs of subtriangular lateralia, which are regularly disposed and symmetrical, the radial areas of the plates being conspicuous and apparently smooth. The length of the specimen is 4·5 mm., and its greatest breadth 3·5 mm. Although this form has a greater number (twelve) of plates than is the case in any of the forms of the family Balanidæ (the number in that family being eight, six, four, or, where all the plates are coalesced, one) it has certain characters in common with the members of that family. In the first place it has at each extremity plates comparable to the rostrum and carina, the carina as usual being the highest plate, and on each side the paired lateralia, which number five in *Protobalanus*, while the highest number in a member of the Balanidæ, namely *Octomeris*, is three. There are also radial areas to the plates, but it is not clear whether all the

[1] See also Darwin, Ray Soc. Monogr. sub-class Cirripedia, Balanidæ, 1854, p. 492.

[2] R. P. Whitfield, in Hall & Clarke, *Palæont. New York*, vol. vii, p. 209, pl. xxxvi, fig. 23, 1888; R. P. Whitfield, Bull. Amer. Mus. Nat. Hist., vol. ii, p. 67, pl. xiii, fig. 22, 1889.

[3] J. M. Clarke, in Hall & Clarke, *Palæont. New York*, vol. vii, p. 210, pl. xxxvi, figs. 24–6, 1888.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EXPLANATION OF ILLUSTRATION ON OPPOSITE PAGE.

FIG. 1.—*Protobalanus hamiltonensis*, R. P. Whitfield. Middle Devonian, Hamilton Group (Marcellus Shales): Avon, Genessee Co., N.Y. (Copied from figure in Hall & Clarke, *Palæont. New York*, 1888, pl. xxxvi, fig. 23.) Shell viewed from above. *c*, carina; *r*, rostrum; *l*, lateralia.

FIG. 2.—*Palæocreusia devonica*, J. M. Clarke. Middle Devonian, Corniferous Limestone: Avon, Genessee Co., N.Y. (Copied from figure in Hall & Clarke, tom. cit., pl. xxxvi, fig. 26.) Shell viewed from above, embedded in *Favosites hemisphæricus*.

FIG. 3.—*Hercolepas signatus*, Aurivillius sp. Upper Silurian, bed *e* (= Lower Ludlow): I. of Gotland. (After Aurivillius.) Side view. *c*, carina; *s*, scutum; *t*, tergum; *c.l.* carino-latera; *l*, lateral; *r*, rostrum.

FIG. 4.—*Strobilepas spinigera*, J. M. Clarke. Middle Devonian, Hamilton Group, Hamilton Shales: Canandaigua Lake, N.Y. (After J. M. Clarke.) *a*, 'dorsal view'; *b*, side view.

FIG. 5.—*Lepidocoleus sarlei*, J. M. Clarke. Middle Silurian, Niagara Shales: Rochester, N.Y. (After J. M. Clarke.) *a*, side view; *b*, diagrammatic transverse section.

FIG. 6.—*Plumulites peachi*, Nicholson & Etheridge, jun. Upper Ordovician, Drummuck Group: Whitehouse Bay, Girvan, Ayrshire. Type-specimen, figured Etheridge, jun. & Nicholson, Mon. Silur. Foss. Girvan, pl. xx, fig. 8. (After F. R. Cowper Reed.) Mr. Cowper Reed figures this as the inner view, but it seems to me to be the outer view. An incomplete individual showing the two median rows of abutting plates (*m*) and the lateral kite-shaped plates (*l*).

FIG. 7.—*Turrilepas wrightiana*, de Koninck sp. Middle Silurian, Wenlock Beds: Dudley, Worcestershire. (After H. Woodward.) *a*, basal half of an individual, showing the two median rows of intersecting keeled plates (*m*) and a row of lateral plates (*l*); *b*, diagrammatic transverse section.

plates have them, or only some; these areas appear to be smooth. No information is available as to the structure of the walls of the shell, which is so characteristic in the members of the Balanidæ. From the figure, however, it would seem that the apices of the three pairs of lateralia nearest the carina meet on a line extending from the apex of the carina to that of the rostrum. There do not appear to be any fractures due to flattening during fossilization, although a portion of the shell near the margin of the whole of the right side has been creased by compression. Since, however, the original describer states that the shell is depressed-convex, one gains the impression that the whole of the shell has not been flattened. If, therefore, the two pairs of lateralia adjoining the rostrum extended near to the median line as do the remaining unbroken lateralia, then it is difficult to understand where the opercular valves could have been situated. A re-examination of the specimen would be interesting, but it may now be said that it is exceedingly improbable that it is even remotely related to the genus *Balanus*, or to any other member of the Balanidæ.

Palæocreusia devonica (Fig. 2) is known by a single shell in which the separate plates cannot be made out; it is ovate in outline, patelliform, with the surface gently conical, and slightly depressed on the posterior slope. The wall of the shell is apparently thin, and the surface marked with faint radiating striæ or elevated lines. A conspicuous furrow extends near to and concentric with the margin. Length 10 mm., width 8·5 mm. As the author states, it brings to mind the representatives of the recent genera *Pyrgoma* and *Creusia*, and since the generic differences from *Creusia* are not readily apparent, the term *Palæocreusia* is used tentatively to express the probability that such differences will eventually be found. It may here be pointed out that, while the recent and fossil forms included in *Pyrgoma* have the shell in one piece, the sutures of the plates rarely being seen, and then only those of the carina, in *Creusia* the four compartments with their radii are quite distinctly seen.

According to Clarke, "The specimen is attached to a colony of *Favosites hemisphæricus* and has at some time been overgrown as far as the aperture by the multiplication of the cell tubes. A portion of the coral was subsequently removed by natural causes, exposing the capitulum, but leaving the tubular basis completely enveloped. The surface of the former still bears traces of the cell walls of the coral. By removal of a portion of the coral near the side of the specimen it is found that the internal cavity is partially filled with soft decomposed chert, the remainder of the cavity filling, the capitulum and the entire coral being silicified. The internal plates, *scutum* and *tergum*, are not preserved . . . The length of the tubular basis can be measured through the aperture for 8 mm., but is probably somewhat greater."

The conspicuous furrow seen near the margin of the shell is explained as probably indicating the line of contact of the wall of the shell with that of the basis, but the furrow seems to me to be too far removed from the margin for this to be the case. In recent forms the wall of the basis is in direct contact with that of the shell at its extreme marginal edge. In Clarke's figure the walls of the coral are shown to extend on to the shell and converge towards the aperture. While this suggests that the figure is somewhat restored, it suggests also that they are ribs of the shell, and not the walls of the coral at all. Had these been the walls of *Favosites* one would have expected to see them closed, and not left open, and to have seen traces of the corallites between them. Moreover, seeing that the shell is so well preserved, one would expect that the basis also would be preserved. Despite the description of Clarke as to the supposed cavity for the tubular basis, one wonders if this could not possibly be a mollusc of the family Fissurellidæ. That family extends back in time probably to the Carboniferous, while the family, which *Palæocreusia* is considered to be a representative of, is not known earlier than the Crag (Pliocene). Mr. Tom Iredale informs me that he has often seen in the Indo-Pacific Oceans, members of the Fissurellidæ attached to, and even overgrown by coral.

Since *Pollicipes signatus*, Aurivillius (Fig. 3), from bed *e* (= Lower Ludlow) of the island of Gotland, in the opinion of the original describer, shows a closer approach to the Balanidæ than do any other of the Lepadidæ, it may more naturally be dealt with here. Only a single specimen is known, and this certainly has the structure of a sessile Cirripede, and bears little resemblance to the capitulum of *Pollicipes*. Its structure is quite unlike that of any other known form, and it is desirable to place it in a new genus, of which the following may suffice for a provisional diagnosis:—

HERCOLEPAS,[1] gen. nov. (Fig. 3, p. 114.)

Sessile barnacles, in which the shell is composed of ten subtriangular plates, the five inner plates sculptured with fine punctæ, the five outer plates about one-third smaller, longitudinally grooved, overlapping on each side the plates of the inner series, with three rows of alternating plates encircling the base and consisting of an inner row of smooth scales, followed by a row of rudimentary spines, and an outer row of comparatively long grooved spines.

Genotype.—Pollicipes signatus, Aurivillius.

Aurivillius has given a very careful and detailed description of *Pollicipes signatus*, and in the absence of an examination of the specimen I do not propose to attempt any redescription of it here. In the figure seven large plates are seen, the three inner plates, counting from the left, being called the scutum, tergum, and carina, while the four outer plates are called the rostrum, lateral, and two carino-lateral plates. Those of the inner series are apparently all of the same shape; their outer surface is covered with minute punctæ, and they have an apico-basal ridge. Those of the outer series are altogether different in appearance, for they are about one-third smaller, and with the exception of the rostrum which has more, the plates have three longitudinal grooves with transverse ridges, the rest of the plate standing out as broad longitudinal folds. As Aurivillius has pointed out, the ornament resembles somewhat that of the Cretaceous *Pollicipes cancellatus*, Marsson (=*Brachylepas naissanti*, Hébert sp., see GEOL. MAG., July and August, 1912). In *Brachylepas*, however, the rostrum and carina have a similar external ornament, as is the case in all Cirripedes with which I am acquainted among either sessile or pedunculate forms; but, if we are to believe Aurivillius' interpretation of the valves in *P. signatus*, the rostrum and carina not only differ greatly in ornament and structure, but belong to different series. It may be impossible to see in the specimen any characters that would guide us in determining which valves are homologous with the scuta, terga, and carina, etc., in other Cirripedes, but it might have helped to give a better idea as to the identity of the valves and their disposition if a view of the specimen from above had been given. At present I am not satisfied with the identification of the valves as given by Aurivillius.

Hercolepas, *Protobalanus*, and *Palæocreusia*, appear to be the only Palæozoic forms that can be referred with any justification to the Cirripedia. *Hercolepas* is an undoubted Cirripede, and while there is very little doubt with regard to *Protobalanus*, there is more doubt in the case of *Palæocreusia*. However this may be, it is of interest to note that all these are sessile forms. With the exception of the supposed attachment scars of Balani recorded by Charles Moore (Quart. Journ. Geol. Soc., vol. xxvi, p. 243, 1870), on shells from Wollumbilla, Queensland, and the problematic '*Balanus carbonarius*' of Petzholdt (see p. 113) from the Carboniferous rocks near Dresden, Saxony, no other record of a sessile Cirripede is known until the Upper Cretaceous.

[1] ἕρκος = an enclosing fence.

The recent sessile Cirripedes are included in the families Balanidæ and Verrucidæ, the latter family consisting of the asymmetrical Cirripedes forming the single genus *Verruca*. *Verruca* extends back in time to the Cretaceous (Upper Senonian), and I have recently maintained (Proc. Zool. Soc., December, 1914, pp. 950 et sqq.) that it was derived from the more primitive form *Proverruca*, occurring also in the Cretaceous (Lower Senonian). In its structure *Proverruca* shows quite conclusively that it must have been derived from a symmetrical pedunculate Cirripede such as *Calantica* (*Scillælepas*), so that the Verrucidæ at any rate were derived from a stalked form.

The Balanidæ consists of the sub-families Balaninæ and Chthamalinæ. We have some evidence to support the supposition that the Chthamalinæ (*Catophragmus*) have arisen from some such form as the Cretaceous (Upper Senonian) sessile Cirripede *Brachylepas*, which in all probability was an offshoot from the stalked Cirripedes forming the genus *Pycnolepas*[1] (Cretaceous, Albian, to Miocene, Helvetian). On the other hand we cannot derive the Balaninæ from that source or from any known form in either the Cretaceous or Jurassic rocks.

Since, however, both the Verrucidæ and the Chthamalinæ can be traced back to the stalked forms existing in the Cretaceous, it seems very unlikely that the remaining 'sessile' group among the recent Cirripedes, the Balaninæ, can have any close relationship with the 'sessile' Palæozoic forms. It is much more probable that the ancestors of the Balaninæ are to be sought for in the Upper Cretaceous or early Tertiary rocks. Further, while among recent Cirripedes the sessile condition is undoubtedly due to a secondary modification of the pedunculate type, it must be kept in mind as a possibility that this may not have been the case among the more primitive forms of the Palæozoic rocks. We can as yet form only a vague idea of the ancestral Cirripede, but there is no need to assume that it possessed a peduncle.

Cirripodites, G. F. Matthew, and Stenotheca, J. W. Salter.

In a paper on the "Faunas of the Paradoxides Beds in Eastern North America, No. 1" (Trans. N.Y. Acad. Sci., vol. xv, pp. 200–7, 1896), Dr. G. F. Matthew has described from the Cambrian certain scattered plates which he ascribes to a new genus *Cirripodites*, and to the genus *Stenotheca*, Salter.[2] The latter genus was found by Salter to include a minute, cap-shaped shell, which he considered to be a Pteropod, but which is now classed among the Gastropods. Even if the forms described by Matthew are not Pteropods or Gastropods, I can see no valid reason for their reference to the Cirripedia, and the comparative thickness of certain of the plates is certainly not in favour of this reference. With regard to the plates included in *Cirripodites*, I fail to see any characters in common with any Cirripede, and I find no reason for dissenting from Matthew's own opinion that "The reference of these plates to Cirripedes is largely a matter of conjecture".

[1] See T. H. Withers, "Some Cretaceous and Tertiary Cirripedes referred to *Pollicipes*": Ann. Mag. Nat. Hist., August, 1914, pp. 199 et sqq.

[2] J. W. Salter in H. Hicks, Quart. Journ. Geol. Soc., vol. xxviii, p. 180, 1872; J. W. Salter, Cat. Camb. Sil. Foss. Mus. Camb., p. 8, 1873.

SCALPELLUM, Leach, and POLLICIPES, Leach.

So far as I am aware only two authors have referred any fossils from the Palæozoic rocks to either of these two genera. In a paper, "Über einige Ober-silurische Cirripeden aus Gotland," Bihang Svenska Vet.-Akad. Handl., Bd. xviii, Afd. iv, No. 3, 1892, Professor C. W. S. Aurivillius describes seven species of *Scalpellum*, namely, *S. cylindricum*, *S. fragile*, *S. granulatum*, *S. procerum*, *S. strobiloides*, *S. sulcatum*, *S. varium*, all from bed *c* (= Wenlock shale) of the island of Gotland. These seven species were all founded on specimens considered to be peduncles, but even apart from the fact that not a single plate of the capitulum had been found with them or even recorded from the same beds, there are many characters that would make one hesitate to refer them to the Cirripedia, let alone to the genus *Scalpellum*. Consequently I have never looked upon them as Cirripedes, and on showing to Dr. F. A. Bather similar fossils from the Silurian of Shropshire as very like some fossils he was working at, he recognized them as the turrets of certain forms of Edrioasteroidea. It was because of their identity in structure with the fossils described by Aurivillius that the Shropshire specimens were at first placed among the Cirripedes in the Geological Department of the British Museum. Dr. Bather has dealt with these forms in his "Studies on Edrioasteroidea" (GEOLOGICAL MAGAZINE, February, 1915, p. 49).

Aurivillius further described and figured (1892, p. 12, fig. 9 of pl.), under the name *Pollicipes validus*, a fossil which he considered to be part of a scutum. It is, indeed, difficult to recognize this as a scutum of *Pollicipes*, or even of a Cirripede. The only suggestion I venture to offer is that it may be a portion of the shell, viewed from the so-called ventral margin, of a species of *Lepidocoleus*, a genus which may or may not belong to the Cirripedia. Although I was fully aware that the specific name was preoccupied by *Pollicipes validus*,[1] Steenstrup, from the Chalk (Danian) of Denmark, I refrained from giving it a name until it was possible to determine from the specimen itself what it really was. Professor J. C. Moberg, however, in a recent paper (Kongl. Fysiogr. Sällsk. Handl., N.F., Bd. xxvi, No. 1, p. 3, 1914), has renamed it as *P. aurivillii*, but does not offer any suggestion as to the nature of the fossil.

The remaining form described by Aurivillius is *P. signatus* from bed *e* (= Lower Ludlow) of the island of Gotland, a form already dealt with on p. 114, Fig. 3.

Dr. R. Ruedemann is the second author to describe Palæozoic fossils as belonging to the genus *Pollicipes*, and in a valuable memoir on the "Hudson River Beds near Albany and their taxonomic equivalents", Bull. N.Y. State Museum, No. 42, April, 1901, he describes and figures (p. 578, pl. ii, figs. 16–24)[2] a number of peculiarly shaped plates found in the Upper and Lower Utica Shale of Green Island, Mechanicsville, N.Y. He considers that these find their homologues in parts of the capitula of *Scalpellum* and *Pollicipes*, notably the latter. For this reason he unites them under the name

[1] Now referred to *Calantica* (*Scillælepas*), Withers, Ann. Mag. Nat. Hist., August, 1914, p. 196.

[2] See also R. Ruedemann, Bull. N.Y. State Mus., No. 162, p. 122, 1912.

Pollicipes siluricus. Since I have not had the opportunity of examining these specimens, and in view of the various shapes of the plates, I do not wish to throw any doubt on their Cirripede nature. It is quite a different matter with regard to their generic determination, and in my opinion the characters shown are quite insufficient for referring them either to *Pollicipes* or *Scalpellum*.

In a recent paper ("Some Cretaceous and Tertiary Cirripedes referred to *Pollicipes*": Ann. Mag. Nat. Hist., August, 1914) I pointed out that, except in the case of the more modified forms of *Scalpellum*, it was difficult to determine from separate valves the proper systematic position of the fossil. This is evidenced by the fact that Darwin and later authors included in *Pollicipes* all the forms that could not be referred to *Scalpellum*, but now that we have better material some have been included in new genera, and others have been shown to be primitive forms of *Scalpellum* (*sensu lato*). Judging from the structure of the remaining Cretaceous forms, there are very few that could possibly belong to *Pollicipes*, and in no case can it be stated positively. This is equally true of the Jurassic species, except that the possibility of their belonging to *Pollicipes* is more remote, and is reduced to fewer species. It is much more likely that many of the Jurassic and Cretaceous species are primitive forms of *Scalpellum*, but some probably belong to other genera. Notwithstanding this, it is still advisable to retain the generic name *Pollicipes* for those Jurassic and Cretaceous species which have been referred to that genus, and are represented by valves insufficient for their more correct determination.

While it may be true that certain forms existed in the Jurassic and Cretaceous rocks, or even in the Palæozoic, in which the valves had apical umbones, and therefore like *Pollicipes* had their growth directed downwards, it does not follow that they belong to *Pollicipes*. They may even, like *Pollicipes*, have had a larger number of valves than *Scalpellum*, namely eighteen to over a hundred, but the fact is that, now we know more of what the complete shell in certain fossil forms was like, we see that the difference lies essentially in the disposition of the valves, not in their number.

On phylogenetic grounds I consider it to be highly improbable, if not impossible, that the genus *Pollicipes*, which is probably a polyphyletic one, and still more *Scalpellum*, could have existed in Palæozoic times, and it is not sufficient to produce a valve with an apical umbo to prove the existence of *Pollicipes*. It is necessary to piece together the greater part of the capitulum before we can gain any idea of the affinities of any form. Apart from this, however, the valves hitherto referred to *Pollicipes* and *Scalpellum* from Palæozoic rocks do not even conform to the old conception of the valves of those genera, for none of the valves has a structure closely approaching even the Jurassic and Cretaceous forms.

TURRILEPAS, H. Woodward, PLUMULITES, Barrande,
LEPIDOCOLEUS, C. L. Faber, and STROBILEPAS, J. M. Clarke.

Since Dr. H. Woodward[1] referred the fossil from the Wenlock Shale of Dudley, originally described by de Koninck as *Chiton*

[1] H. Woodward, Quart. Journ. Geol. Soc. London, vol. xxi, p. 486, 1865.

wrightianus,[1] to the Cirripedia under the new genus *Turrilepas*, many fossils from the Palæozoic rocks have been referred to the Cirripedia under the names *Turrilepas*, *Plumulites*, *Lepidocoleus*, and *Strobilepas*. While it is doubtful if certain of the fossils even belong to these genera, it certainly still remains to be proved that any of them belong to the Cirripedia.

Strobilepas is known only by one species, *S. spinigera*, J. M. Clarke (Fig. 4, p. 114),[2] based on a single specimen from the Middle Devonian (Hamilton Group) of New York, and in this specimen the plates are somewhat displaced. J. M. Clarke (1888, p. lxiii) has given a restoration of it, and from this we learn that there are four columns of plates, of which the outer two are large and of equal size. One of the two intervening columns consists of a few very small plates, and the other is modified into a series of spines, which lie opposite the series of small plates. The apical extremity is terminated by a circular, conical plate, against the sides of which lies the first plate in each column. It appears to form a completely enclosed shell, and is less like a Cirripede than the other genera, for if it be a Cirripede it is difficult to imagine where the cirri could have protruded in search of food.

Lepidocoleus is known by several species, namely the genotype *L. jamesi*,[3] Hall & Whitfield (originally described as *Plumulites jamesi*[4]), from the Hudson River Group of Cincinnati, *L. sarlei*,[5] J. M. Clarke (Fig. 5, p. 114), from Niagara Shales of New York, *L. polypetalus*,[6] J. M. Clarke, from the Lower Helderberg Group of New York, *L. illinoiensis*,[7] Savage, from the Upper Oriskany Group of Illinois, and a species, *L. suecicus*,[8] recently described by Professor J. C. Moberg from the Upper Ordovician of Sweden. The genus is represented also to my knowledge in the Wenlock Beds of Dudley, in the Ordovician of Bohemia, and in the Middle Devonian of Moravia. The record from Bohemia is based on four plates in the Geological Department of the British Museum, accompanied by one of Barrande's original labels, which reads "*Squamula bohemica*, Barr. D-. Mt. Kosow". Barrande states in his Monograph (*Syst. Silur. Bohême*, vol. i, Suppl., p. 565, 1872) that in 1856 certain fossils were distributed to the British Museum under the generic names *Plumulites*, *Anatifopsis*, and *Squamula*. He later, however, considered that there were two generic types only, not feeling justified in retaining the proposed genus

[1] De Koninck, Bull. Acad. Sci. Belgique, ser. II, tom. iii, p. 190, 1857.

[2] J. M. Clarke in Hall & Clarke, *Palæont. New York*, vol. vii, p. 212, pl. xxxvi, figs. 20–2, 1888.

[3] C. L. Faber, Journ. Cincinnati Soc. Nat. Hist., vol. ix, p. 15, pl. i, figs. A–F, 1886.

[4] J. Hall & R. P. Whitfield, Geol. Surv. Ohio, *Palæontology*, vol. ii, p. 106, pl. iv, figs. 1, 2 (*non* fig. 3 = *Turrilepas wrightiana*), 1875.

[5] J. M. Clarke, *Amer. Geol.*, vol. xvii, p. 143, pl. vii, figs. 1–6, 1896.

[6] Ibid., figs. 7–8.

[7] T. E. Savage, *Amer. Journ. Sci.* (4), vol. xxxv, p. 149, figs. 1–3, 1913.

[8] J. C. Moberg, "Om Svenska Silurcirripeder": Kongl. Fysiogr. Sällsk. Handl., N.F., Bd. xxvi, No. 1, p. 13, pl. ii, figs. 1–11, 1914. Since the present paper was sent to press Professor Moberg has published some additional notes, Geol. Fören. Stockholm Förhandl., Bd. xxxvi, Hft. vi, p. 492, 1915, which in no way affect what is here written.

Squamula. The above four specimens are therefore some of those which he originally intended to include in *Squamula*, and they appear to be identical with the plates figured by him (p. 576, pl. xx, figs. 22–4, 1872, especially fig. 22) as *Plumulites squamatula*, a species recorded from Étage D and E. Their reference to *Plumulites* was probably the reason for giving up *Squamula*, but that genus would have been quite justified since *Plumulites squamatula* undoubtedly belongs to the genus *Lepidocoleus*, C. L. Faber (1887). Meanwhile the name *Squamula* has no nomenclatorial validity.

In *Lepidocoleus* there are only two vertical columns of plates apparently overlapping on the median line, with slight alternation, and the shell is capable of opening along the narrow free edge.

Turrilepas (Fig. 7, p. 114) and *Plumulites* (Fig. 6, p. 114). These two genera differ from *Lepidocoleus* in having a greater number of vertical rows of plates. Of the actual number there is some difference of opinion, but since I am able to state positively that there are only four in *Turrilepas*, it is probable that there are four rows also in *Plumulites*. Much misconception has arisen with regard to these two genera, mainly owing to the fact that the structure of them has been misunderstood, with the result that while many species have been distributed between them, some authors give priority to *Plumulites* and others to *Turrilepas*. The whole history need not here be gone into, but it is clear that these two genera are quite different. The main difference lies in the two median rows of plates, for while in *Turrilepas* (Fig. 7) they are keeled or sharply bent longitudinally, and alternate with each other, in *Plumulites* (Fig. 6) the plates are not keeled, are altogether different in shape, and do not alternate, their inner margins abutting. The plates on each side of the keeled plates in *Turrilepas* are not minute as described by Dr. Woodward and Professor Moberg, but are about the same size as the keeled plates. They resemble the leaf-like plates in *Plumulites*, except that they are not so much produced at their apical ends and do not possess a median longitudinal fold. While it is gratifying to note that Professor Moberg in his above-quoted paper, "Om Svenska Silurcirripeder," has recognized the difference between *Plumulites* and *Turrilepas*, a view I have held for some time, it may be said that it is not British palæontologists alone who have confused these two genera. Everyone who has written on these forms has done so, and the authors of the genera even claimed priority each for his own genus, thinking that they were synonymous. But Mr. F. R. Cowper Reed [1] doubted whether they were synonymous, although they are so regarded even in the last edition of Zittel–Eastman. Professor Moberg conveniently gives on the same plate figures of all the above genera, but, seeing that he distinguishes between *Plumulites* and *Turrilepas*, it is surprising to find that he figures, not *Plumulites bohemicus*, Barrande,[2] which should be regarded as the genotype of *Plumulites*, a species very like *P. peachi* (Fig. 6), but *P. folliculum*, Barrande,

[1] F. R. C. Reed, "The Structure of *Turrilepas Peachi* and its allies": Trans. Roy. Soc. Edin., vol. xlvi, pt. iii, No. 21, p. 519, 1908.

[2] J. Barrande, *Systême Silurian Bohême*, Supplement to vol. i, p. 569, pl. xx, fig. 1, 1872.

a form in which Barrande could not discern the ornament so characteristic of *Plumulites.* It is even impossible to make out the contour of the plates, or their number, which J. M. Clarke thought composed only two rows, so this form is very probably distinct from the genus *Plumulites.* The state of preservation of all the examples of *P. folliculum* as contrasted with the other forms would suggest this. There is no definite evidence that the single plate referred by Barrande (1872, pl. xx, fig. 10) to this species really does belong to it.

In conclusion, it may be said that we know very little of the relationship to one another of *Lepidocoleus*, *Plumulites*, and *Turrilepas*, and very little is known even of the structure of their shells. In none do we know the relation of the animal to the shell, and except for the ornamentation and the downward growth of the plates there seems to be no other character advanced in favour of their reference to the Cirripedia.

I wish to express my thanks to Dr. F. A. Bather and Dr. W. T. Calman for their valuable assistance with this paper.

IV.—The Work of Professor Lacroix on the Laterites of French Guinea.

By L. Leigh Fermor, D.Sc., A.R.S.M., F.G.S., Geological Survey of India.

(Concluded from the February Number, p. 82.)

Alluvial Laterites or Lateritites (Latérites alluvionaires).

ALL the phenomena hitherto noticed have been worked out for the case of rocks altered *in situ*, but they also take place in the products of transport resulting from the demolition of laterites *in situ.*

In these *lateritic alluvia* (*alluvions latéritiques*) or *lateritites* the zone of departure is the base of the alluvium itself, in which the hydrolysis of any aluminous silicates still remaining is continued, whilst the upper part forms a ferruginous cuirass, differing from that of the non-transported laterites only when quartz debris or transported fragments of rock, themselves usually lateritized, are present. When the alluvium is constituted by fine particles the conditions are favourable for the formation of very regular ferruginous pisolites, and in Professor Lacroix' opinion the specimens of constant aspect so frequently seen in collections from many tropical countries probably come from such occurrences.

Lacroix adopts for these rocks my term *lateritite,* proposed for detrital or secondary laterites, which, it is seen above, are subjected to a continuance of the same processes that led to the formation of the primary laterite. (See analysis No. 16, Table II, *infra*, for a very impure lateritite with 31 per cent quartz, 30 per cent clay, and 39 per cent lateritic constituents.) He also finds in many parts of Guinea a conglomerate composed of small fragments of gibbsitic laterite, mixed with clastic products, in particular quartz, derived from neighbouring rocks, and constituting a true sedimentary rock intermediate between the type described in the preceding paragraph and the *latérite d'alluvions* to be noticed in the next paragraph.

It should be noted here, although it is not so stated by Lacroix, that this conglomerate is also covered by my definition of lateritite.

Lateritized Alluvium (*Latérites d'alluvions*).

This type of laterite is perhaps the most widely developed in Guinea, existing as a continuous ferruginous crust to ordinary non-lateritic alluvium in the coastal regions of Guinea between the sea and the foot-hills of Futa-Jallon and in the plain lying between the eastern limits of these mountains and the Niger. In this type of laterite the iron is not derived from the material undergoing lateritization, but is derived from the rock underlying the alluvium, as I gathered from a personal discussion with Professor Lacroix. This iron rising in solution from the underlying rocks becomes oxidized and precipitated so as to be superposed on the clastic elements of the alluvium, which are themselves more or less unaltered. The iron is therefore of extraneous origin. For this form of laterite Lacroix proposes to use my term *lateritoid* as follows (p. 323):—

"Peut-être serait-il bon de distinguer par un nom spécial ses latérites d'alluvions de celles formées aux dépens de roches en place, et, dans ce cas, on pourrait les appeler *latéritoïdes*, en donnant de l'extension au terme proposé par M. Fermor pour désigner des roches latéritiques de l'Inde, résultant de l'envanissement de grès, de schistes, par des oxydes de fer et de manganèse et constituant souvent des minerais de ces métaux!"

My term *lateritoid* was proposed for the case of lateritic rocks formed by the metasomatic replacement of non-lateritic rocks by lateritic constituents presumed to be of extraneous origin; and in all the cases described by me the rock undergoing replacement was an old, properly consolidated rock. Professor Lacroix' 'lateritoid' was formed at the expense of a recent alluvium, by the introduction of extraneous iron oxide, and should be regarded as a lateritoid only if the iron oxide has introduced itself by metasomatic replacement into the alluvium and has not merely superposed itself on the latter by filling up interstices.

Professor Lacroix assures me that the introduction of iron has been effected by a replacement of the cement between the grains of quartz in the alluvium, the alumina in the *latérite d'alluvions* being derived from the decomposition of the aluminous silicates in the cement. In India the quartz of a quartzite may suffer complete replacement by iron or manganese oxides with formation of lateritoid, but in the Guinea *latérite d'alluvions* the quartz itself does not appear to have suffered replacement, and it is evident that the two cases are not strictly comparable as regards mode of formation. In Table II of this article are shown two analyses (Nos. 14 and 15) of *latérites d'alluvions* (lateritized alluvium) from Guinea. Professor Lacroix excludes 24·51 per cent of quartz from No. 14 and 67·39 per cent of the same constituent from No. 15, so that No. 14 appears to contain 63 per cent of lateritic constituents and 35 per cent of clay, and No. 15 to contain 79 per cent of lateritic constituents and 21 per cent of clay. This gives a misleading impression, and in calculating the mineralogical compositions (shown in the same table)

TABLE II.—ANALYSES OF LATERITES DERIVED FROM MICA-SCHIST AND ALLUVIUM.

Original Rocks.	Mica-schist.			Alluvium.		Laterite, etc.
Locality.	Siguiri.	Fatoya.		Not stated.	The Tinkisso.	Not stated.
Position in Section	Zone of Concretion	Zone of Concretion	Zone of Concretion (cuirass).	(?) Crust.	(?) Crust.	Zone of leaching.
Name of Rock.	Pisolitic bauxitic laterite.	Quartzose aluminous laterite.	Pisolitic bauxitic laterite.	Lateritized alluvium or siliceous 'lateritoid'	Lateritic alluvium.	Lateritite.
Number.	11	12	13	14	15	16
SiO_2	0·72	1·22	4·37	16·85	9·91	13·12
TiO_2	1·02	0·19	0·66	0·46	1·44	1·68
Al_2O_3	50·62	46·31	39·79	22·99	22·41	25·61
Fe_2O_3	17·69	17·65	32·26	42·85	52·53	12·97
CaO	0·17	0·19	0·17	0·07	tr.	0·13
MgO	—	—	—	—	0·43	0·04
H_2O	25·80	21·40	21·05	16·78	13·26	15·81
Quartz	6·23	13·33	1·70	(24·51)	(67·39)	30·58
	102·25	100·29	100·00	100·00	99·98	99·94
Mineral Composition:—						
$Al_2O_3 . 2SiO_2 . nH_2O$ [1]	1·55(2)	2·6 (2)	9·4 (2)	27·4 (2)	6·5 (1)	30·2 (3)
$Al_2O_3 . 3H_2O$ (colloidal)[2] } bauxite	58·6	43·4	33·7	9·4	—	22·1
$Al_2O_3 . H_2O$ (colloidal) } bauxite	13·9	19·9	16·5	0·5	5·4	—
$2Fe_2O_3 . 3H_2O$ (limonite and stilpnosiderite)[3] .	20·7	20·6	37·7	37·8	20·1	15·15
$TiO_2 . H_2O$ . . .	1·25	0·2	0·8	0·4	0·6	2·1
Quartz . . .	6·2	13·3	1·7	24·5	67·4	30·6
	102·2	100·0	99·8	100·0	100·0	100·15

Notes.—Mineral compositions recalculated by me because Lacroix takes no account of quartz and titania. There must be a misprint in the first analysis.

[1] The value of n is shown in brackets in each case, n being 2 per kaolinite. In analysis No. 16, 0·30 % H_2O has been added to bring n up to 3.

[2] In analyses 12 and 13 the hydrate is gibbsite, and not colloidal.

[3] In analyses 11, 12, and 13, some hematite is present, so that the amount of $Al_2O_3 . H_2O$ must be less than that shown.

of these rocks I have reinstated the quartz, as it is impossible otherwise clearly to understand the case. No. 15 is then seen to contain only 26 per cent of lateritic constituents, and the question of the application of the term lateritoid does not arise. This rock is clearly only a lateritic sandy alluvium. No. 14 shows 48 per cent of lateritic constituents, and is therefore on the border-line between a *lateritic alluvium* and a *siliceous lateritoid,* if the same limiting percentages be adopted for the lateritoids as for the true laterites.

Should examples be found in which the replacement has progressed further with production of rocks carrying over 50 per cent of lateritic constituents when quartz is taken into account, then the term *lateritoid* might be applied, especially if the replacement has affected the quartz itself. At present all that can be admitted on the evidence is that these *latérites d'alluvions* from Guinea tend towards conversion into a particular variety of lateritoid. They are perhaps best designated *lateritized alluvium.* The consideration of this case shows the undesirability of disregarding quartz in classifying laterites as proposed by Professor Lacroix.

V. Conditions of Formation of Laterite.

On approaching the problem of the origin of laterite, the first thought that strikes one is that there is an apparently fundamental difference between the modes of decomposition of aluminous silicates in temperate and in tropical regions. For in *temperate regions* the end product is a *clay*, in which the original aluminous silicates are represented by hydrated aluminium silicates approximating in composition to kaolinite, whilst in the *tropics* the end product is *laterite*, in which the original aluminous silicate is represented by a mixture of hydrated aluminium oxides. The two processes may be expressed by the following chemical equations:—

$$(1)\ \underset{\text{Orthoclase.}}{K_2O.Al_2O_3.6SiO_2}+CO_2+2H_2O = \underset{\text{Kaolinite.}}{Al_2O_3.2SiO_2.2H_2O}+K_2CO_3+4SiO_2.$$

$$(2)\ \underset{\text{Kaolinite.}}{Al_2O_3.2SiO_2.2H_2O} + H_2O = \underset{\text{Bauxite.}}{Al_2O_3.(2\pm1)H_2O} + 2SiO_2.$$

Reaction No. 1 belongs to the group of changes characteristic of Van Hise's zone of katamorphism, and is doubtless of exothermic character, so that it should take place in both temperate and tropical climates, as is the case. Reaction No. 2 is a further stage in the process of decomposition, namely, a hydrolysis of the hydrated aluminium silicate with formation of the hydrated aluminium oxides characteristic of laterite. The thermal character of this second reaction is of great importance. If it be exothermic, then it is possible to regard it as representing a further stage in the changes expressed in equation No. 1, to be promoted possibly by the same agents; whilst if it be endothermic it will require for its promotion an external supply of heat. There are apparently no experimental data bearing on this question, but from inspection of the equation there seems to be no obvious reason why its thermal character should be different from that of equation No. 1, as each of them involve the liberation of silica from a silicate.

Sir Thomas Holland, however, evidently regards the second reaction as endothermic, for he speaks of a reversal of the chemical reaction.[1] The higher temperatures of the tropics as compared with the temperate regions would properly not be sufficient to produce this reversal, and therefore Holland, seeking for the operation of some other form of energy that could produce exothermic results, suggested the vital influence of life in the form of bacteria,[2]

[1] Trans. Inst. Min. Met., xix, p. 454, 1910.
[2] Geol. Mag., 1903, pp. 61–4.

by which he meant, according to a later explanation, not bacteria of any specific kind, but vegetable life of all sorts, of which the lowest forms would be the most potent, because the most abundant. Vegetable life is vastly more active in the tropics than in temperate regions, and, as pointed out by Holland, owing to the absence of a true winter in the tropics, it is not compelled to pass a part of the year in enforced inactivity, as in temperate regions. Holland's suggestion is undoubtedly a valuable contribution to the problem, and cannot be rejected as long as the thermal character of the second equation remains doubtful; or if the equation be truly endothermic, until some other agent be found more capable of providing the energy required.

Although, roughly speaking, clays and laterites may be regarded as characteristic respectively of temperate and tropical climes, yet they are not confined to their respective regions. True clays are found very commonly in the tropics; e.g. in India we have them in abundance in the Nilgiri Hills as weathering products of the charnockite series, whilst they are associated with laterite in many parts of India. Lacroix in this memoir has, as already noted, shown that the aluminous silicates of the original rocks sometimes pass directly into gibbsite, and sometimes change first into a hydrated aluminium silicate, which passes afterwards into hydrated oxides. Furthermore, bauxitic oxides are known to occur in variable amounts in the clays of temperate regions, and on investigation will probably be found to be more widely and commonly distributed therein than was suspected until recently. In a paper published about the same time as Professor Lacroix' monograph, Mr. M. G. Edwards[1] gives the results of the examination of a large series of analyses of clays of the United States. Out of 244 analyses in which the free and combined silica had been separated, 108, or 44 per cent, showed an excess of alumina above that required for the kaolinite ratio of SiO_2 to Al_2O_3 of 2 : 1. The percentage of bauxite thus detected in these clays ranges from 0·54 to 43·5; and that the distribution of these bauxitic clays is not a function of latitude is shown by the fact that two analyses from Florida, the most southern state, show an average of only 0·8 per cent of bauxite, thirty-six analyses from Georgia show an average of 11·8 per cent of bauxite, and twelve analyses from Iowa, a northern state, an average of 31·7 per cent of bauxite. There are also southern states with a high percentage of bauxite in their clays, and northern states with a low percentage.[2]

It is evident, therefore, that neither form of decomposition is confined to its characteristic region, as would be expected were both equations of the same thermal character. Professor Lacroix refers to Holland's hypothesis, but without referring to the thermal aspects of the problem he reasons from the continuity he has established in certain cases between the formation of clay and of laterite, and thinks it more natural to regard both modes of alteration as due to reactions of the same order, manifesting themselves with greater intensity in tropical countries because of special climatic conditions. He does

[1] "The Occurrence of Aluminium Hydrates in Clays": *Economic Geology*, ix, pp. 112–21, 1914.

[2] See also H. Ries, op. cit., p. 402, 1914, for criticisms of Edwards' paper.

not, however, go further into this matter as he thinks the solution of the problem of the origin of laterite should come from the experimental side, and that it would be profitless to discuss this question again without the support of laboratory experiments.[1] Instead, the author prefers to state the conditions under which lateritization takes place and those under which it does not.

In the first place it is evident, Professor Lacroix thinks, that *lateritization is not the result of a direct attack by the atmosphere*, nor by running rain-water, as is shown by the freshness of basic and syenitic rocks in cliffs and denuded surfaces.[2] On the contrary, *lateritization is everywhere intense where the slope of the ground is low enough to permit the infiltration of water and allow it to remain for a long time in contact with the rocks.* One must also give great weight, even according to Professor Lacroix, to the *action of vegetation*, which develops with extreme rapidity under such conditions, so that one cannot accept the idea recently advanced by Vageler[3] that the clayey decomposition of temperate climes is due to the action of humic acids, whilst in tropical countries the silicates undergo hydrolysis, due to the rarity or absence of humus.

For the development of a ferruginous cuirass the most favourable topographical forms are certainly the tabular plateaux provided by diabase flows, and valley-bottoms of very low gradient. In proportion as superficial concretion progresses the conditions become more and more unfavourable for the existence of vegetation, which finally to a large extent disappears. If this view be correct, then *the sterility of the bowals is not the cause, but the consequence of lateritization commenced under a cover of vegetation.* It thus becomes evident that Holland and Lacroix are really in agreement in so far as they regard the action of vegetation as a factor in the formation of laterite.

The climatic conditions already referred to are those, as the author notes, to which Dr. Maclaren has attached so great an importance for explaining the laterite of India, namely *the alternation of very humid and very dry seasons.*[4] At the beginning of the wet season the water

[1] See Meigen, *Geol. Rundschau*, ii, pp. 197–207, 1911, for a recent though incomplete résumé of theories of lateritization.

[2] This first proposition is, however, not self-evident.

[3] *Fühling's Landw. Zeitung*, lix, p. 873, 1910 (Lacroix).

[4] Geol. Mag., p. 546, 1906. In his contribution to the discussion of J. M. Campbell's paper, Trans. Inst. Min. Met., xix, p. 414, 1911, Maclaren states that while he regards an alternation of wet and dry seasons as essential in humid regions, nevertheless a truer statement may be given, as follows: "Laterization may take place in intra-tropical regions in a desiccated zone overlying a zone charged with oxidized waters, capillary attraction translating the waters from the lower to the upper zone." "The upper zone, in humid regions with heavy monsoon rainfall, where the ground water level is near the surface, may be at the surface; in more arid regions it may be as much as three feet below." This modification is to account for the laterite in arid parts of Western Australia, believed by Maclaren still to be growing. This condition, namely, alternation of wet and dry seasons, does not, however, fit all known cases. Thus, as shown by Scrivenor, there is no alternation of seasons at Malacca; but it has yet to be shown that the laterite of Malacca is still in process of formation, or at least that its formation was not initiated under different climatic conditions. For the present, however, it is necessary to admit the formation of laterite in regions of constant rainfall.

sinks into the ground, saturation being realized after some weeks; copious springs then burst forth everywhere, permitting the removal of soluble products; this must be the time when the zone of leaching grows at the base and the phenomena of *départ* or leaching are completed near the surface. At the end of the rainy season this flow gradually ceases, the ground dries, the solutions become concentrated, and are drawn up by capillarity into the upper zone; there the dissolved products are deposited little by little, the water finally evaporating at the sun-heated surface, where the precipitation and concretion of the hydrogels is completed.

The conditions of lateritization given above fit satisfactorily the mineralogical and chemical data given in Professor Lacroix' memoir; but it is not evident that the description of the happenings in the rainy season is based on personal observation, for the author's visit coincided with the winter.

VI. The Age of Laterites.

Professor Lacroix finally states his views on the age of various sorts of laterite, regarding it as probable that all the phenomena considered in his memoir are still in a state of active evolution, although no direct observation of this can be made, except in the case of ferruginous concretionary action at the surface of the cuirass. But he gives evidence to show that the process of lateritization must be a slow one. There are laterites of at least two ages, as proved by the eroded cliffs of 'fossil laterite' contrasted with the *latérite d'alluvions* of the valleys, these two types corresponding in position to our Indian high-level laterite and low-level laterite. He finally concludes that (p. 351)—

> "Le début de la latérisation en Guinée est fort ancien et date peut-être de plusieurs périodes géologiques, sans qu'il possible de songer à aucune précision en l'absence de toute formation sédimentaire datée."

In conclusion, it is perhaps permissible to regret that this admirable piece of work should contain several numerical mistakes in connexion with the analyses, and that the author has not seen fit to illustrate his memoir with at least a sketch-map of the localities mentioned, nor to separate clearly the conclusions firmly founded on observations such as the sequence of mineralogical changes characterizing lateritization from those based less securely on probability rather than on observation, such as the conclusions brought forward in Section V of this paper.

REVIEWS.

I.—A Guide to the Fossil Remains of Man in the Department of Geology and Palæontology in the British Museum (Natural History), Cromwell Road, London, S.W. With 4 plates and 12 text-figures.

DURING the last two years the lively controversies concerning the significance and interpretation of the skull-fragments found by Mr. Charles Dawson near Piltdown have bewildered and confused the interested public no less than a not inconsiderable number of scientific men. Under these circumstances it was highly desirable that a simple statement of the facts, devoid of all technicalities, should be made available in an easily accessible form. The Guide which Dr. Smith Woodward has written supplies this want. For fourpence anyone can now obtain an admirably lucid and concise description, illustrated with a series of photographs and diagrams, of the famous Piltdown fragments, together with an account of the remains of *Pithecanthropus*, the Heidelberg jaw, and the series of representatives of the Neanderthal race. A sketch of our knowledge of the fossil Primates provides an excellent setting for the notes on the remains of early man, for it serves to explain their zoological rank and horizon.

After referring to the coming of the "Age of Mammals" the Guide describes the place of the Primates among the Mammalia, and summarizes the present state of our knowledge of the past history of the Order as it is revealed by fossilized remains of Lemuroids, Lemurs, Monkeys, and Apes. The consideration of *Pithecanthropus* serves to introduce the account of the antiquity of man. The circumstances of Mr. Dawson's discovery of *Eoanthropus* are then set forth, and an account is given of the objects found in association with it and the reasons for assigning the human remains to an early Pleistocene horizon.

The concise account of the fragments of the Piltdown skull and the excellent series of illustrations put the reader in possession of all the essential facts, and quite definitely justify the creation of a new genus of the Hominidæ to which to assign this representative of a hitherto unknown type of primitive generalized humanity.

Many books have been written within recent years with the object of explaining and interpreting the remains of fossil man, but most of them are unsatisfactory. Some of them put forward fantastic ideas as to the antiquity of man and the course of human evolution. Others, again, confuse their readers by quoting masses of conflicting statements. This small Guide, brief though it be, is perhaps the best account of the present state of our knowledge that has yet appeared. For it is a simple, sane, and easily understood statement of admitted facts and the inevitable and indisputable inferences to be drawn from them.

In a work written for the general public, complex technical points have necessarily been explained in simple language, which may perhaps at times offend the scientific purist who likes to hide his ignorance behind high-sounding technical terms—in many cases not meaning very much. For instance, exception has been taken to the statement that "certain parts [of the brain] remain scarcely more developed than they are in a modern child" (p. 14). It would perhaps have been more accurate to express this by saying that the parts of the brain of *Eoanthropus* corresponding to those areas which in the modern human being attain their full development last of all are conspicuously ill-developed. But it seems to me that in a Guide intended primarily for the general public the simpler explanation given by Dr. Smith Woodward is justifiable, and that such a criticism as I have quoted savours of pedantry. The Guide is not a manual intended solely for experts, although experts, whether anatomists, geologists, or anthropologists, might learn a good deal from it. In fact, no more useful introduction to the study of fossil man could be put into the hands of students.

The "Conclusion" of the Guide is such an admirably concise and sane summary of the present state of our knowledge and so characteristic a sample of the quality of the whole of the work as to be worth quoting in full:—

"The general conclusion is that man, having a skeleton essentially identical with the existing one, has lived in western Europe for a long period during great changes of climate, much alteration in geographical contour, and the dying-out of numerous wild quadrupeds. He was here long before the British Isles were separated by sea from the mainland of Europe. His immediate predecessor was a form of man (the Neanderthal or Mousterian) which more nearly approached the apes in the retreating forehead, the prominence of the bony brow, and the large size of the face. The skeleton of his trunk also exhibited a combination of more ape-like features than are known in any single human skeleton of later date. Still earlier Heidelberg man, though with typically human teeth, had a much more retreating bony chin, suggestive of close relationship with the apes. Finally, Piltdown man, which is at least as old as the Heidelberg race, and probably older, had both lower jaw and front teeth as nearly as compatible with their working on a human skull of normal width. His skull, however, though with a very large face, and in some respects the most ape-like known, appears at first sight to be contrary to expectation in the steepness of its forehead and the absence of the modern ape's characteristic brow-ridges. But it must be remembered that, in accordance with a well-known law, the skull in the adult ancestral apes of Miocene times (still to be discovered) probably resembled that of the very young existing ape, not that of a full-grown individual. Just as the bony brow-ridges are acquired during the life of each individual existing ape, so the race of apes began without them, and only gradually acquired them as an adult character through successive generations. The Piltdown skull, therefore, probably resembles the skull of the truly ancestral apes much more closely than does the later Neanderthal skull, in which the bony brow-ridges may be a mark of peculiar degeneration. The *Pithecanthropus* from Java may be another degenerate."

The admirable conciseness and adequacy of this judgment appeal most strongly to those who have critically studied the conflicting mass of literature on the points at issue.

The publication of this Guide at the present time is peculiarly opportune, not only because it puts within the reach of everyone the information to enable him to discriminate between the true and the false in the recent literature relating to primitive man, much of which is distinguished by a reckless disregard of the caution and the precision of statement usually observed in scientific work, but also because it will enable everyone interested in such matters to appreciate the meaning of new discoveries which the near future will reveal. It is a matter of common knowledge that several important discoveries of ancient human remains are even now awaiting description, and no doubt many more important fragments will come to light now that the attention of the public is being educated to the importance of saving such material as chance may reveal. Professor Graebner tells me that a few weeks before the present war was declared two complete skeletons of Neanderthal man, with animal remains and implements in association with them, were found in situ during the excavation of a railway cutting near Bonn. The remains of a Pleistocene human skeleton were recently found in South Africa; and a skeleton from East Africa, concerning which fantastic accounts appeared in the public Press a year ago, still awaits description. Even in Australia a fossilized human (child's) skull has just come to light, thirty years after it was picked up by a boundary-rider on the Talgai station (near the village of *Pilton*!), not far from Warwick on the Darling Downs of Queensland. On August 22 this specimen was exhibited and described by Professors Edgeworth David and Wilson at the recent meeting of the British Association in Australia. The skull was found in a spot rich in the remains of *Diprotodon* and other extinct marsupials. It was discovered in a position precisely similar to that in which these extinct animals occur, and its state of mineralization is identical with that of many of these fossils, now in the Brisbane Museum, from the same area. Professor David has no doubt that the human being whose skull has been thus recovered was a contemporary of the *Diprotodon* and the *Thylacoleo*. At the same meeting illness prevented Mr. Etheridge, the Director of the Australian Museum in Sydney, from demonstrating the fact that the Dingo was also a contemporary of these extinct animals. Thus we have this complementary evidence to substantiate the belief that, even before the great marsupials had become extinct, Man with his dog had ferried across "Wallace's line", even if no other straits were then open, and made his way into Australia. Quite apart from the question of its age, this fossilized Proto-Australian skull is of peculiar interest, for it is provided with exceptionally large teeth and great projecting canine teeth worn on their posterior borders (by the lower premolars), unlike any other human teeth. Professors David and Wilson intend to publish a full account of this interesting specimen in the near future.

For the proper appreciation of the precise significance of such new information as this which the future will reveal Dr. Smith Woodward's little Guide-book should be invaluable.

G. E. S.

II.—The Transportation of Débris by Running Water. By G. K. Gilbert. United States Geological Survey, Professional Paper 86. pp. 263. 1914.

THIS elaborate report embodies the results of a lengthy experimental investigation of the laws of transportation of debris by running water. The work was done in a specially equipped laboratory at the University of California, Berkeley, during the years 1907–9. Unfortunately, the artificial streams used in the laboratory cannot be made to conform with the meanderings, variable discharge, and forms of cross-section of natural alluvial streams, and the author is obliged to admit that the primary purpose of the investigation, which was to determine for rivers the relation of the load swept along the bed to the more important controlling factors, was not accomplished. Although the gap between the river and the laboratory has not yet been bridged, much valuable information was obtained which is directly applicable to hydraulic transport and river engineering.

Streams carry debris in various ways which can be grouped together under the headings of hydraulic *suspension* and *traction*, the latter referring to what is sometimes called the bottom load. Each of these two modes of progression may be further divided according to the nature of the bottom. In natural streams the bed is usually composed of debris which is similar to the material of the load. In artificial channels, like flumes and pipes, the bed is rigid. The Berkeley experiments were designed specifically to investigate stream traction and flume traction, since there is a marked contrast between the laws controlling each case. Generally, the measurement of the suspended load in a river is only a matter of routine and patience, but the measurement of the tractional or bottom load is difficult. Knowledge of the average ratio between the suspended and the tractional load would be of great value to geologists and engineers. Humphreys and Abbot estimated the tractional load in the case of the Mississippi to be 11 per cent of the suspended load. Guérard in a study of the Rhône found the suspended load to be less than 25 per cent of the whole. Gilbert took measurements of the two loads in the Yuba River and came to the conclusion that they were approximately equal. These data are probably the best on record, but their wide variability is a serious reflection on the value of denudational studies in relation to the wearing down of the lands and to the measurement of geological time.

The factors which control the movement of the traction load are numerous and complex, for the law of control in the case of each factor is qualified by all the other factors. The slope and discharge of the stream, the form of its channel, the fineness of debris, and the velocity are all controlling factors. Of these factors most attention has been devoted to velocity, and it has been generally assumed, though erroneously, that the load carried varies with the sixth power of the velocity. This deductive law strictly refers only to the maximum size of the grains or pebbles which a given current is competent to move. The actual law is too complex for analysis and generalization. In the Berkeley experiments an attempt was made to compare capacity for traction load with the mean velocity V_m of the stream. The following empirical average results were obtained: (1) slope constant; V_m varies with discharge; capacity $\propto V_m^{3\cdot2}$. (2) discharge constant; V_m varies with slope; capacity $\propto V_m^4$. (3) depth constant; V_m varies with slope and discharge; capacity $\propto V_m^{3\cdot7}$. In each case the size of the debris carried provides a further interfering factor. If fine material be added to coarse the total load is increased, and even the load of coarse material is greater than before.

There is little doubt that, from the geological aspect, experiments of these kinds, while of considerable theoretical interest, serve only as a check to undue speculation. The transportation of debris by rivers, and the degrading and aggrading of their beds are phenomena which must be studied in the rivers themselves.

Arthur Holmes.

III.—Report on the Recent Great Eruption of the Volcano Stromboli. By Frank A. Perret. Smithsonian Report for 1912. Pub. 2200. pp. 285–9, pls. i–ix. 1913.

In 1907, and again in 1912, the normal activity of Stromboli was broken by paroxysmal eruptions which indicate that this volcano is sharing in the general increase of activity of the other Mediterranean volcanoes. The 1907 eruption produced a crater 200 metres in diameter, and was marked by Strombolian explosions in which large masses of incandescent plastic lava were ejected, accompanied by clear vapours, alternating with Vulcanian explosions in which dense black volutes of ash arose from the collapsing walls as the lava column sank. The 1912 eruption increased the diameter of the crater to 300 metres. The 1907 lava, which had partly obstructed the conduit, was ejected in irregular solid blocks (olivine basalt). Enormous quantities of ash were formed directly from liquid lava, and scoriaceous lapilli of the same composition were also ejected. Strombolian and Vulcanian explosions were even more clearly defined than in 1907. The crater is now partly filled with collapsed material from the cone, which tends to confine the gases until they gather strength to break through and form an ash cloud. The author's most interesting observation is based on the hazardous experience of being completely enveloped in a cloud of gas and ash proceeding directly from the crater during a paroxysmal eruption. Since no distressing effects were produced, the conclusion is inevitable that gases such as HCl, SO_2, H_2S, CO_2, etc., which are abundant during phases of minor activity, must be practically absent during paroxysmal phases. Since 1907 the normal activity of Stromboli has undergone a radical change which has deprived the volcano of its former title, "The Lighthouse of the Mediterranean." Indeed, so seriously is this the case that a lighthouse is to be erected on Strombolicchio, a monolith of lava which rises from the sea near Stromboli.

IV.—An Introduction to the Geology of New South Wales. By C. A. Süssmilch, F.G.S. 8vo; pp. xviii + 269, with 92 figures and folding coloured map. Sydney: Angus & Robertson, Ltd., 1914. Price 7*s.* 6*d.* net.

To anyone living in New South Wales, this introduction to its geology should be invaluable. Clearly written, excellently illustrated, and of convenient size, it forms a handbook that every New South Wales geologist should possess. It is not, however, lacking in points of general interest to the casual reader outside the State. To mention only a few of these points—the occurrence of glacial conditions in the Cambrian (p. 17) and their recurrence in the

Permo-Carboniferous (p. 144) and in the Pleistocene (p. 218) of this area, raises questions of more than local interest. The account of available coal in the State is cheering in these days of rapid fuel-consumption. It is estimated that at the present rate of production the available supply will last for another 12,000 years (p. 139). The origin of the artesian water (p. 171); the Cretaceous fossils preserved in opal at White Cliffs (p. 183); the identification of the Tertiary flora with the present day coastal 'brush' flora of very limited range and requiring a warmer, moister climate than that which most of the State now enjoys (p. 203); the post-Tertiary movements which brought about this change in the flora (pp. 212–15); the correlated dwindling in size of the vertebrates from the Tertiary Period onwards (p. 205); the limited area of the Pleistocene glaciation (p. 219); all are examples of interesting points.

The text appears to be singularly free from misprints, but 'spilite' and 'spillite' both occur on p. 61; and 'Queesland' on p. 174 is another slip; while the sentence on p. 181 beginning 'At some localities' lacks construction. 'Outcrop' is frequently used as a verb, and 'intrude' as a transitive verb, neither of which usages, however convenient, is commendable. 'Jasperoid' (p. 62) and 'granitoid' (p. 254) for 'jasper-like' and 'granite-like', 'subsidence area' (p. 152) for 'area of subsidence', and 'Lower' and 'Upper Marine Sea' for 'sea in Lower' and 'sea in Upper Marine times' (legends to figs. 37 and 51) are blemishes; while the equal of 'Trach'te bo'ld'r horiz'n' on p. 129 will only be found in railway time-tables, grocery lists, and printed matter of a similar standing.

Turning to technicalities, we think the statements "The Polyzoa were more abundant than they had ever been before" (p. 133) and "The Gasteropoda . . . were larger than they had ever been before" (p. 134) too sweeping, and strictly inaccurate for a scientific work; "the following genera . . . *Neuroptera*" (p. 135), and "Coralline limestones" (p. 75, presumably for "limestones containing Corals"—not Corallines, an old term for Polyzoa), are inaccuracies. 'Seed-spores' (p. 142) is an extraordinary word. It does not seem in accordance with modern ideas to combine Polyzoa with Brachiopoda in a single phylum Molluscoidea; and the genus *Ammonites* (p. 184) is rather out of date. However abundant *Heliophyllum* may be in Australian Silurian strata, it is best known as a Devonian not a "typical Silurian" Coral (p. 64). Such points might easily be readjusted in a later edition, and have not much weight against the excellencies of this volume.

The illustrations add considerably to the value and interest of the book, and deserve high praise, especially the geological views, of which fig. 44 is a particularly beautiful example. Fig. 47 (of columnar basalt) is very clear; but, while a figure or two is always useful in a geological photograph, the population of fig. 46 is such as to distract the mind from the geological features illustrated. The sections are clearly drawn, and of these fig. 52, showing trough-faults in the Upper Coal-measures, is especially striking. In the figures of fossils the magnification should be given, and it would be useful if the source of the figure, where not original, were noted.

There are several maps showing the distribution of land and water in New South Wales at particular geological periods, and the frontispiece is a clearly-printed, general, geological map of the State. Finally, a glossary (a merciful provision when such words as 'regolith' and 'monadnock' are used) and an index complete this useful handbook.

V.—Brief Notices.

1. The Production of Graphite in 1913. By E. S. Bastin. Mineral Resources of the United States, year 1913. Part II. pp. 181–251. 1914.

THIS report contains all the information on graphite which has appeared in earlier reports of the United States Geological Survey, amplified and brought up to date wherever possible. It includes a valuable account of the physical and chemical properties of graphite, and of the origin and uses of the mineral. The deposits of the United States are described in detail, and descriptions are also given of graphite deposits in Ceylon, Korea, Madagascar, and Mexico. The report is completed by a full bibliography of literature bearing on the occurrence, production, properties, and uses of graphite.

2. Useful Minerals of the United States. Compiled by Samuel Sanford and Ralph W. Stone. United States Geological Survey, Bulletin 585. pp. 250. Washington, 1914.

Lists of useful minerals appeared in the issues of the *Mineral Resources of the United States* for the years 1882 and 1887, but have not been published since. In the interval the mining industry of the United States has increased enormously, and a revised list has long been called for. In view of its length it is now issued as a separate publication. It gives the locality of the principal deposits of useful minerals in the various States, and a glossary showing the composition and character of each mineral and its principal occurrences is added.

3. Summary Report of the Geological Survey, Department of Mines, for the Calendar Year 1913. pp. ix + 544. Ottawa, 1914. Price 20 cents.

This report, which is unusually belated even for an official return, testifies to the extent and varied nature of the work undertaken by the Survey. During the year it was exceptionally heavy owing to the additional field work called for in connexion with the handbooks compiled for the visit of the International Geological Congress the following year (1913). Field work in Canada appears to be not without danger; one of the staff, Dr. J. D. Trueman, unfortunately lost his life owing to a canoe accident, and a topographer was laid up in hospital for some months as the result of an encounter with a grizzly bear. Some progress is reported in fitting up the Natural History Museum, but is greatly handicapped by the lack of properly equipped workrooms and storerooms. Mr. D. D. Cairnes completed the geological section along the 141st parallel between the Yukon and Porcupine Rivers, which is part of the geological section across the

Northern Cordillera undertaken in co-operation with the United States, and found that the formations are dominantly of sedimentary origin, and range from Recent to probably pre-Cambrian age.

4. The Ore Deposits of North-Eastern Washington. By Howland Bancroft, including a section on The Republic Mining District by Waldemar Lindgren and Howland Bancroft. United States Geological Survey, Bulletin 550. pp. 215, with 26 figures and 19 plates. Washington, 1914.

The district described by the author comprises mainly the whole of Stevens and Ferry Counties. The geology could not be determined with certainty owing to the absence of fossils, but the rocks may be referred to the Proterozoic, Palæozoic, Mesozoic, and Cenozoic eras. One of the most conspicuous rocks is an intrusive granite. The mineral resources are very varied, and include gold, silver, lead-zinc, copper, iron, tungsten, nickel, antimony, and molybdenite deposits, and also minerals used as fluxes. The various mines are described in detail, and reference to the memoir is facilitated by an excellent index.

5. Electric Activity in Ore Deposits. By Roger C. Wells. United States Geological Survey, Bulletin 548. pp. 78. Washington, 1914.

As the result of considerable investigation in the laboratory the author concludes that electric action may have played no small part in the deposition of ores. Many metalliferous minerals can conduct electricity and act as electrodes and as conductors of electric currents in ore deposits. The chemical difference producing the greatest effect appears to be that existing between oxidizing and reducing solutions. Pyrites is so inert to many solutions as to function electrically like unattackable electrodes for long periods, thus making oxidizing or reducing solutions available for producing electric currents in ore deposits.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

February 3, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Gravels of East Anglia." By Professor T. McKenny Hughes, M.A., F.R.S., F.G.S.

The author discusses the sources from which the subangular gravels that cover such large areas in East Anglia can have been derived.

He points out that their great variety of fracture, colour, etc., proves that they cannot have come directly from the Chalk, nor from Boulder-clay derived directly from the Chalk, nor from the Lower London Tertiaries, none of which contain subangular gravels, but only beds of pebbles, and those mostly of small size.

The character of the flints in the gravels indicates that they have been derived from surface-soils which have been winnowed and shifted by soil-creep, rain, and streams, until arrested on the terraces and flats of the valleys.

The dry land of Miocene age was the first over which the flints of our gravel beds could have received that subaerial treatment which they all seem to have undergone. There was then no Boulder-clay to protect and obscure the Chalk-with-Flints.

Then came the submergence which let in the Crag sea. This rapidly invaded the land, not giving time to reduce the flints to pebbles, but burying remains of animals and plants in coarse subangular gravel. In time the subsidence affected more distant shores, and compensating rises of mountain regions far away began to modify climatal conditions; ice floated southwards, stranding at various depths according to size, ploughed up and crumpled the shore-deposits, and dropped masses of far-transported material. It is not difficult to distinguish the old shore-deposits, even when they have been crumpled up, from the foreign material introduced by the floating ice.

When the land had sunk so low that the wind- and tide-waves could not sort the material, it remained, as brought, a boulder-clay, which is therefore widely spread over the peneplain of the East Anglian heights, and is generally above the gravel and sand of the advancing sea.

Where the sea was able to work longer at pounding and rolling the flints, immense beds of pebbly shingle or of sand are the result.

The Plateau Gravel is traced from section to section across the country, and the characteristics by which it can be recognized are pointed out.

Since an irregular land-surface was thus depressed beneath the sea, one might expect that in some of the deeper valleys deposits older than the submergence might be detected. Also, seeing that the land has slowly risen again many hundred feet, we ought to have evidence of the subaerial denudation which has been going on since the land began to rise.

Thus the author starts with the definition of three important ages of long duration, and proceeds to refer some of the best exposed gravel deposits of East Anglia to one or other of them.

They are, in descending order—

(1) The stage of which the Barnwell Gravel is taken as a type.
(2) The stage of which the Plateau Gravel is the most important representative.
(3) The stage to which he suggests that the Barrington Beds may belong.

The rest of the paper consists of descriptions of sections and discussion of evidence derived from fossil remains.

2. "The Pitchstones of Mull and their Genesis." By Ernest Masson Anderson, B.Sc., M.A., F.G.S., and E. G. Radley.

The pitchstones here discussed occur with extraordinary frequency, intruded into the Tertiary plateau-lavas of the eastern portion of the Ross of Mull, as well as in less number in other parts of the island.

They fall into two main divisions, distinguished by the absence or by the presence of porphyritic felspars. Those of the non-porphyritic class are the most prevalent, and usually form the central portion of sills or inclined sheets. The marginal portion of these intrusions is crystalline or stony. The petrological characters of these pitchstones and their more crystalline margins are such that they seem to warrant the grouping of the rocks under a new type-name, and the name leidleite has been chosen. The porphyritic pitchstones occur as flat or gently inclined sheets; they also are associated with a more crystalline phase, and have been grouped under the type-name inninmorite.

The relation of the stony margins of the pitchstone intrusions to their glassy centres is usually seen clearly. A typical leidleite may have 5 feet of pitchstone in the centre, with margins of stony matter 3 feet thick on each side. Occasionally the central glassy portion may be split up by stony partings.

A feature that occurs very frequently in these rocks is what has been termed 'sheath and core' structure. In this case the stony base and top of an intrusion send off narrow sheets of stony character which traverse the glassy portion in a branching and sinuous manner. The glassy nature of the cores is clearly not due to a greater rapidity of cooling; but, with the object of ascertaining the reason for the devitrification, a chemical investigation of both the glassy and stony portions was undertaken.

It has been found that there is a much greater percentage of water given off from the rock at 105° C. in the case of the glassy variety, and the authors suggest that the escape of this excess of water, soon after the consolidation of the rock, has resulted in the devitrification of the sheaths and margins.

II.—Mineralogical Society.

January 26, 1915.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

S. Kôzu: The Dispersion of Felspar. By the most refined methods the dispersions in the three principal directions were determined for various members of the felspar group.—F. P. Mennell: Note on the Colour of some Alluvial Diamonds and of Pyrrhotite. The colour, usually green, of the diamonds in the gravels of Somabula, Rhodesia, is superficial, and probably due to infiltration, presumably of iron salts, while the stones were lying where they now occur. Pyrrhotite is tin-white in colour when fresh. The cause of its rapid alteration was discussed.—Professor G. Cesàro: Crystals of Calomel from Spain. The crystals, which were pale-yellowish in colour, imperfectly transparent, from 1 to 3 mm. in size, and displaying the forms 100, 111, 311, were most irregularly developed.—Professor G. Cesàro: General Formula for the Birefringence of a Crystal-plate in terms of the Angles which its Normal makes with the Principal Optical Axes. The approximate formula is obtained by supposing the mean index of refraction to become infinite, while the differences between it and the greatest and least indices remain constant.—

Professor G. Cesàro: On a Numerical Relation of the Sum of the Symmetry-axes situated in the Symmetry-planes of a Polyhedron. If $N \,.\, \Lambda_n$, $P \,.\, \Lambda_p$, $Q \,.\, \Lambda_q$ . . . are the axes of symmetry lying in the planes of symmetry, then $4\ \{Nn\ (n-1)+Pp\ (p-1)+Qq\ (q-1)+ \ldots\} +1=C$, and the number of planes of symmetry is given by $X=\frac{C+1}{2}$.

OBITUARY.

ARTHUR ROOPE HUNT, M.A. (Cantab.), F.L.S., F.G.S.

Born January 8, 1843. Died December 19, 1914.

With the close of the past year another of our old friends has been taken from us, and one who for a quarter of a century was not only a friend, but a frequent contributor to the pages of the Geological Magazine.

Arthur Roope Hunt was descended from an old Devonshire family, who had resided for generations in or near Dartmouth. He was the son of Mr. Arthur Hunt, partner in the firm of Messrs. Hunt, Roope, & Teage, wine exporters of Oporto, and there, in 1843, young Hunt was born. But his residence in Portugal was only of brief duration. When only 8 or 9 years of age he left with his parents hurriedly in an English war vessel, as the lives of the British residents in Oporto were endangered by a revolution.

His family settled in Torquay in 1852. Here he commenced his English education under the tuition of the Rev. Townsend Warner, whose pupils included the present Lord Rayleigh, one of Hunt's school, college, and lifelong friends. Another youthful companion, only two years his senior, was afterwards to become Field-Marshal Lord Grenfell.

Those early years must have been very happy ones, for although always a delicate lad, Arthur Hunt enjoyed abundant outdoor pleasures and had many friends willing to share his society and encourage his pursuits.

It must be borne in mind that Torquay had been, from an early date, a very active centre of scientific life in all its diversified branches. The well-known Torquay Natural History Society, which was founded by William Pengelly and others, now in its seventieth year, afforded an admirable focus to a very wide circle of men of leisure and education resident in South Devon. In addition to Mr. Pengelly, Hunt's earliest instructor in geology, may be mentioned the naturalist, Mr. Philip Henry Gosse, the Rev. T. R. R. Stebbing, the Rev. G. F. Whidborne, Mr. John Edward Lee, Mr. E. B. Tawney, Mr. Daniel Pidgeon, Mr. R. H. Worth, and in later years Mr. Arthur Champernowne, Mr. W. A. E. Ussher, Mr. A. J. Jukes-Browne, and Mr. Alexander Somervail, to all of whom Hunt was intimately known.

Mr. Hunt displayed much knowledge of engineering, and had his constitution been more robust he might have carried on much more elaborate investigations; but his health forbade it, and he devoted himself to open-air pursuits, chiefly to geology, marine physics, and zoology.

Mr. Edmund Gosse, writing of his father, Philip Henry Gosse (the well-known author of many works on marine zoology), says: "When he [Gosse] took sailing excursions he often had the company of Mr. Arthur Hunt of Torquay, a young naturalist of knowledge and enthusiasm who possessed a yacht, the *Gannet*, in which the friends undertook frequent scientific excursions, especially over the sandy *zostera*-beds in Torbay, among the little archipelago which lies off Hope's Nose, at the mouth of Brixham Harbour, and off Berry Head."

At 18 A. R. Hunt proceeded to Trinity College, Cambridge, where in 1864 he took his degree of M.A. He then studied law, "ate his dinners" at the Inner Temple, and was duly "called to the Bar", but he never practised.

After spending a few years in the business house of a cousin in the city of London, he abandoned town permanently, and in 1874 settled down at Southwood, Torquay, only varying his residence to visit his estate at Foxworthy, Moreton Hampstead.

In 1870 he was elected F.G.S., and in 1884 he became a Fellow of the Linnean Society.

In company with Mr. Pengelly he devoted much time to the exploration of Kent's Cavern, and wrote many papers thereon. What he learned from Pengelly he applied to the Scottish cave at Borness, Kirkcudbrightshire, which he explored with the co-operation of Adam Corrie & W. Bruce-Clarke,[1] a very complete and excellent piece of cave-work.

Accompanied by Pengelly, Tawney, and other of his friends, he made numerous geological investigations in Devonshire and neighbouring counties. He also specially studied the subject of ripple-mark and its origin and the submarine geology of the English Channel off the coast of Devon and Cornwall. Mr. Hunt secured numerous rock-specimens brought in by the Brixham trawlers, many of which were sliced and examined microscopically and reported upon by him. With Mr. R. N. Worth he devoted special attention to the age of the Dartmoor granites, the Devonian rocks of South Devon, and the metamorphic schists and Lizard serpentines, and published numerous papers thereon. Over these subjects he was both the giver and the recipient of much keen criticism from General MacMahon, Professor Bonney, and others. Many of these controversies were carried on in the pages of the Geological Magazine, the Transactions of the Devonshire Association (1892–7), and other journals.

For many years he attended the meetings of the British Association, and he took a keen interest in the papers read in the various sections, and joined in the discussions with his usual enthusiasm.

Like other able young men of science Hunt felt attracted by and tempted to cope with questions relating to many and diverse branches of research, and delighted, as the Athenians of old, "to tell or to hear of some new thing." Had he devoted himself exclusively to any one of the varied subjects he at times pursued with so much ardour, he might have earned a more distinguished name for himself in science outside Devonshire, where, and especially in Torquay, he will be long

[1] See Proc. Soc. Antiq. Scotland, vol. x, 1873–4, illustrated by six octavo plates prepared from photographs by A. R. Hunt.

remembered. The stimulus of *necessity* was, however, wanting, and Mr. Hunt could allow himself the pleasant freedom of the amateur to take up and lay aside a number of diverse pursuits, to turn from the microscope and the study of igneous rocks to pen a long letter to the local or provincial press, voicing his views on the various actions of the Municipal Authorities and the needs of Torquay and its harbour, and on the hundred and one other matters a Corporation undertakes.

In early years I paid many pleasant visits to my old friend Mr. John Edward Lee, antiquary and geologist, at Torquay. There I met Arthur Roope Hunt, and with him I studied ripple-mark, and in his boat we visited the raised beaches on the Thatcher. He also showed me his model arrangement for demonstrating the force and velocity of waves and their action on the stability of lighthouses. He was full of enthusiasm and interest, and I look back to my friendship with him as a most pleasant memory. The loss of such a versatile man of genius will be much felt by the wide circle in Devonshire and elsewhere with whom he came in contact, either personally or by correspondence, for he was a great letter-writer.

Between 1890 and 1913 Mr. Hunt frequently contributed to the Geological Magazine, and to the Transactions of the Devonshire Association from 1873 to 1913. His paper on "Ripple-mark" was read by Lord Rayleigh before the Royal Society in 1882 (see Proc. Roy. Soc.). Other products of his pen appeared in the publications of the Torquay Natural History Society, the Proceedings of the Royal Dublin Society, the Linnean Society, the British Association, the Society of Antiquaries of Scotland, and in the *Westminster Review*. He published altogether nearly a hundred papers, whilst his letters on scientific and general topics in the *Torquay Directory* and other newspapers probably reached several hundred in number. He was a past President of the Torquay Natural History Society, one of the founders and managers of its Museum, and its frequent benefactor. On no less than three occasions he felt compelled to decline the proffered honour of the presidency of the Devonshire Association.

In his yachting days he was a member of the Royal Dart Yacht Club; he was a former Captain of the Torquay Golf Club; and Captain of the Miniature Rifle Club at Walls Hill. Amongst his varied attainments he was an enthusiastic musician, and an accomplished photographer.

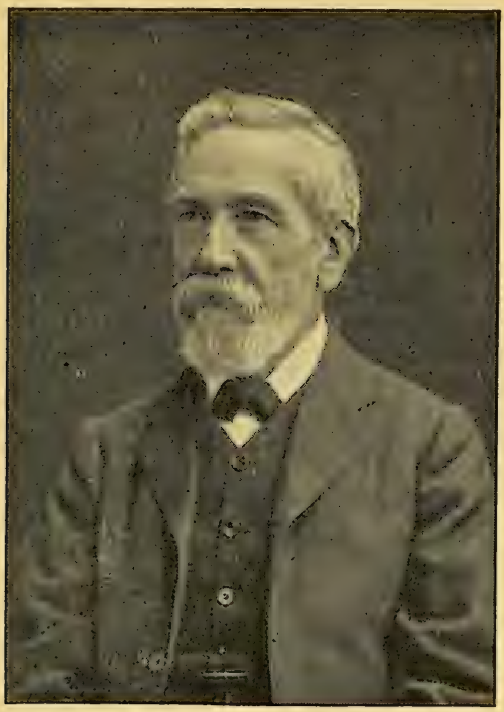
Mr. Hunt leaves a widow and a son, Mr. C. A. Hunt, M.A., Barrister-at-Law, and one married daughter, Mrs. Ernest Smith.

H. W.

FREDERICK WILLIAM RUDLER, I.S.O., F.G.S., Etc.

Born July, 1840. Died January 23, 1915.

The death of Mr. F. W. Rudler took place at Tatsfield, Surrey, on January 23, and will cause the deepest sorrow to a very wide circle of geological and other scientific friends, by whom he was highly esteemed for his wide literary and scientific attainments, and beloved for his gentle and kindly disposition. His modesty almost amounted to shyness. He was a friend to those in trouble and a generous helper to those in need. Some fifty-five years have passed away since Mr. Rudler began his scientific career as a student at the Regent Street Polytechnic Science and Art Classes, where his remarkable talents resulted in his being awarded two gold medals (the highest award) in one year; and this doubtless led to his appointment, in 1861, to the post of Assistant Curator in the Museum of Practical Geology in Jermyn Street. In 1876 he was appointed lecturer in Natural Science in the University College of Wales at Aberystwyth, where he remained for three years and, in addition to



F. W. Rudler.
1910.

his lectures, established the Museum of the College, afterwards unfortunately destroyed by fire. In 1879, on the death of Mr. Trenham Reeks, Mr. Rudler was recalled to Jermyn Street Museum at the urgent request of the Director, Sir Andrew Ramsay, where he undertook the duties of Registrar of the Royal School of Mines and Curator and Librarian of the Museum of Practical Geology. The former post Mr. Rudler held until the final removal of the School of Mines to South Kensington, and the latter until his retirement in

1902. His duties during these twenty-two years were strenuous and trying owing to the great and critical changes in the establishment which took place, changes much deprecated by our old friend, who was dearly attached to the Survey and its Museum. The most obvious of these changes was the final removal of the Royal School of Mines and the division of the Library, nearly half the books being carried off to South Kensington, and the sad depletion of the Museum by the elimination of the unique collections of pottery and of metal-work.

Mr. Rudler served under four well-known Directors, Sir Roderic Murchison, Sir Andrew Ramsay, Sir Archibald Geikie, and Dr. J. J. H. Teall, and so much were his services appreciated by them and by the Science and Art Department at South Kensington that, upon his retirement, he received from King Edward the Imperial Service Order.

As a mineralogist Mr. Rudler was most accomplished, being able to identify and name any mineral specimen at sight, and could state its properties and locality with wonderful precision.

Beyond his official duties Mr. Rudler was also an eloquent speaker and a voluminous writer. He was intimately connected with a number of our scientific societies, and for many years took a prominent part in the British Association meetings. His long courses of lectures for the Society for the Extension of University Teaching were highly appreciated, and he was constantly called upon to lecture upon special subjects in which he greatly excelled. Much of his writing was devoted to works on technical science; the 1875 edition of Ure's *Dictionary of Arts and Manufactures* was chiefly, one may say, his writing. Many articles of his will be found in the *Encyclopædia Britannica*, in Thorpe's *Dictionary of Applied Chemistry*, in Muir's *Dictionary of Chemistry*, and elsewhere. Nor must one omit to mention the *Guide to the Museum of Practical Geology* and his *Catalogue of Pottery and Porcelain*. His scientific reviews are to be found scattered through some of our leading journals for years past, and his connexion with the *Athenæum* was continued until his death.

Mr. Rudler was elected a Fellow of the Geological Society in 1870, and was awarded the Lyell Medal by the Council in 1903, in recognition of his great services to geological science by his lectures and his writings. He joined the Geologists' Association in 1874, and was elected President in 1887–9. Special reference must be made to his Presidential Address, "Fifty Years Progress in British Geology," and to his masterly essays on Experimental Geology.

On the occasion of the Fourth Session of the International Geological Congress, held in London September 17–23, 1888, under the Presidency of Professor Prestwich, F.R.S., Mr. F. W. Rudler was appointed Honorary Treasurer, and fulfilled the difficult task to the great advantage of the members of the Congress, from whom he received grateful thanks.

Some few years ago our dear friend, finding it necessary to give up very much of his lecturing and literary labours, retired to his quiet home at Tatsfield, where he resided until he passed away peacefully to his rest.

E. T. N.

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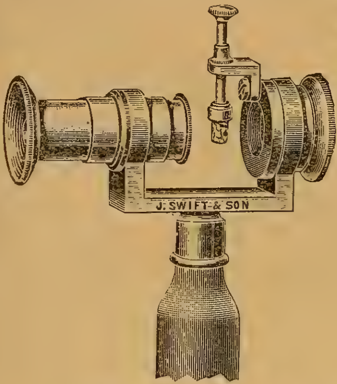

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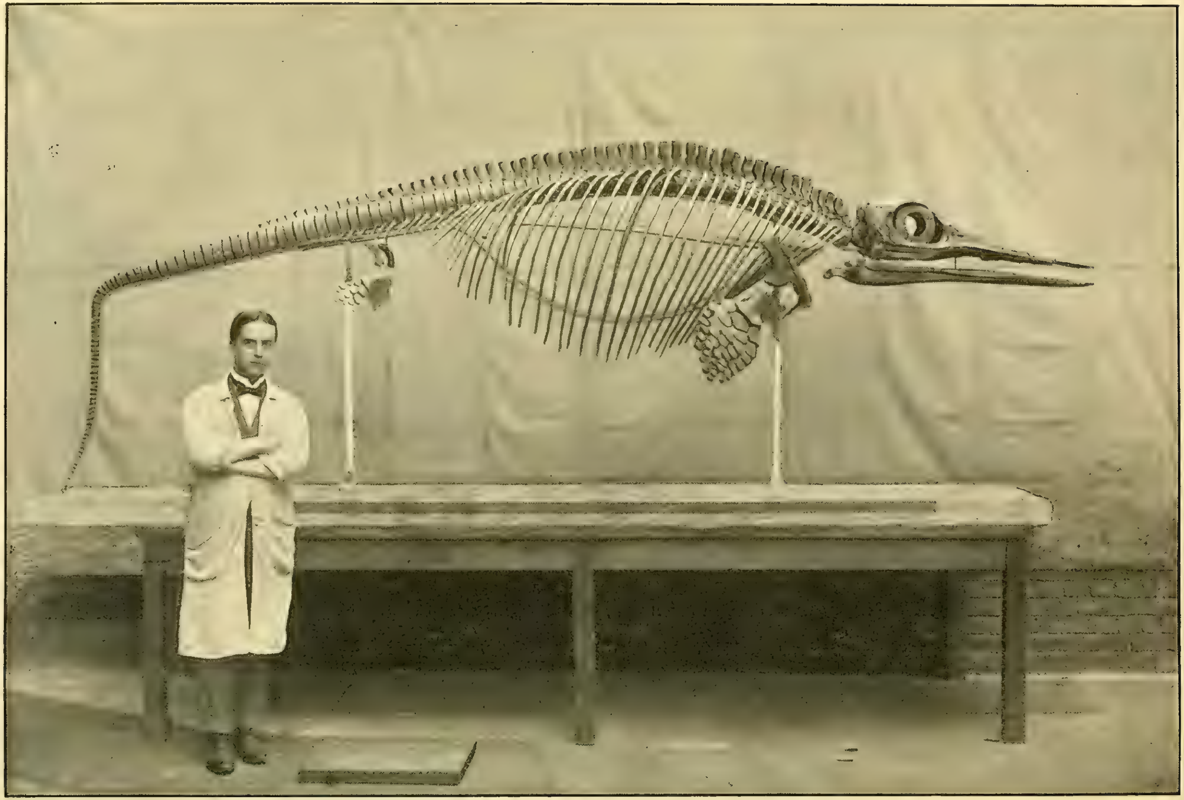

L. T. Parsons, Photo. Bale Sons & Danielsson Ltd.

Skeleton of *OPHTHALMOSAURUS ICENICUS*, Seeley.
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(Length 13 feet 6 inches.)

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ORIGINAL ARTICLES.

I.—Note on a Mounted Skeleton of *Ophthalmosaurus icenicus*, Seeley.

By C. W. Andrews, D.Sc., F.R.S. (British Museum, Natural History).

(PLATE V.)

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ONE of the most important additions recently made to the Gallery of Fossil Reptilia at the Natural History Museum, is a mounted skeleton of the highly specialized Ichthyosaur known as *Ophthalmosaurus icenicus*, Seeley. This reptile presents many peculiarities, for the most part indicating a very high degree of adaptation for life in the open sea and for rapid movement through the water, probably sometimes at considerable depths. In fact, *Ophthalmosaurus* may be regarded as representing among the Reptilia the swiftly swimming toothed-whales among the Mammalia, and it is interesting to note that the similar mode of life in the two cases has produced in some respects similar modifications. Thus the front paddles are enlarged, the hind ones reduced; in whales the latter have disappeared altogether. Again, there was a large caudal fin, vertical in this case, and the head was elongated, the snout sharp, and the neck so short as to be practically non-existent. The enlargement of the fore-paddles is brought about by the presence of a very large pisiform bone, which together with the radius and ulna articulates with the humerus, thus forming a very broad base for the expanded terminal portion of the paddle. Another striking peculiarity is the great reduction of the dentition, the teeth in the adult being very small and confined to the front of the jaws. *Baptanodon*, an American form very closely allied to, if not identical with, *Ophthalmosaurus*, was for a long time regarded as toothless. This reduced dentition, so unlike what is usually found in members of the group, must indicate some considerable change in the nature of the food, but what this was is unknown.

This specimen has been mounted with great skill and neatness by Mr. L. T. Parsons, so that any portion can be removed for examination without much difficulty. It is made up almost entirely from portions of three individuals: the mandible and skull, except the occipital region belong to one (R. 3702); the occiput, the sclerotic rings, the vertebral column nearly to the bend of the tail, the ribs, shoulder-girdle with the fore-paddles, and the femora to a second (R. 3893); while the remainder of the caudal region was supplied by a third

(R. 4124). The pelvis and some ribs have been modelled from other specimens. All the material employed was collected with his usual skill and care by Mr. A. N. Leeds, F.G.S., from brick-pits in the Oxford Clay in the neighbourhood of Peterborough, whence he also obtained the fine skeletons of *Cryptocleidus* and *Peloneustes* exhibited in the same gallery.

As usual when a skeleton is mounted in this way, it gives a very different impression from that derived from the examination of the separate bones, or even from the crushed specimens by which the Ichthyosauria are usually represented. One of the most remarkable features is the manner in which the long anterior ribs, borne on the vertebræ behind the axis, are crowded back, so as to pass within the scapulæ. That this arrangement actually occurred is shown in some of the crushed Liassic specimens, especially in the remarkably well-preserved examples from Holzmaden. There were about fifty pairs of ribs in all. The caudal fin must have been very large, the deflected portion of the vertebral column running down in the ventral lobe consisting of about fifty vertebræ; it is possible that as mounted this terminal portion of the vertebral column is bent down a little too sharply, the angle between it and the rest of the backbone being rather more obtuse.

The length of the skeleton as mounted is 13 ft. 6 in. (412 cm.), of which the head occupies 3 ft. 2 in. (96·5 cm.).

II.—A Deep Bore at Seascale in Cumberland.

By Professor J. W. Gregory, F.R.S., M.I.M.M., D.Sc.

During the years 1906 to 1909 a bore was sunk at Seascale on the coast of Cumberland, 9 miles south-eastward from St. Bees, in the hope of reaching a continuation of the Coal-measures which, south of Whitehaven, end against the Trias. This bore reached the depth of 3,200 feet, and it was then still in the Red Sandstone Series, which it entered beneath 20 feet of drift. Owing to the kindness of Mr. Forster Brown, I received a copy of the bore section, and from Mr. Fleming Smith, of Cleator Moor, manager of Vivian's Boring and Exploration Company, Ltd., who carried out the boring, further information regarding the bore, two samples of the core, and a copy of the journal for the lowest 180 feet. As the bore record is of especial geological interest, I am indebted to Mr. Forster Brown for permission to publish it.

Section of Borehole at Seascale.

	Thickness.		*Depth.*	
	ft.	*in.*	*ft.*	*in.*
Surface	20	5	20	5
Sandstone	584	0	604	5
Red Shale	5	0	609	5
Sandstone	1,463	6	2,072	11
Red Shale joints . . .	3	0	2,075	11
Sandstone	37	0	2,112	11
Red Shale joints . . .	2	0	2,114	11
Sandstone	13	6	2,128	5
Red Shale partings . . .	4	0	2,132	5
Sandstone	6	0	2,138	5
Red Shale joints . . .	6	0	2,144	5

	Thickness. ft.	in.	Depth. ft.	in.
Sandstone	3	6	2,147	11
Red Shale partings	9	0	2,156	11
Sandstone	94	0	2,250	11
Red Shale	2	0	2,252	11
Sandstone	53	0	2,305	11
Red Shale partings	12	0	2,317	11
Sandstone	23	0	2,340	11
Red Shale joints	9	0	2,349	11
Sandstone	23	0	2,372	11
Red Shale	45	6	2,418	5
Sandstone	20	0	2,438	5
Red Shale partings	6	6	2,444	11
Sandstone	7	6	2,452	5
Red Shale partings	8	0	2,460	5
Sandstone	81	6	2,541	11
Red Shale joints	5	6	2,547	5
Sandstone	148	0	2,695	5
Red Shale partings	9	6	2,704	1
Sandstone	53	6	2,758	5
Red Shale joints	6	0	2,764	5
Sandstone	63	0	2,827	5
Red Shale partings	7	6	2,834	11
Sandstone	72	6	2,907	5
Red Shale joints	1	6	2,908	11
Sandstone	56	0	2,964	11
Red Shale joints	1	0	2,965	11
Sandstone	9	6	2,975	5
Red Shale partings	5	6	2,980	11
Sandstone	8	0	2,988	11
Red Shale partings	6	6	2,995	5
Sandstone	24	0	3,019	5
Red Shale partings	3	0	3,022	5
Sandstone	177	7	3,200	0

Mr. Fleming Smith has sent me the following copy of the section book for the lowest part of the bore :—

	ft.	in.	ft.	in.
			3,022	5
Red Sandstone	16	1	3,038	6
,, ,, spar joints	1	7	3,040	1
,, ,, ...	8	11	3,049	0
,, ,, spar joints	4	7	3,053	7
,, ,, ...	10	9	3,064	4
,, ,, spar joints and shale partings	8	3	3,072	7
,, ,, ...	5	0	3,077	7
,, ,, spar joints	4	2	3,081	9
,, ,, ...	4	7	3,086	4
,, ,, shale joint	3	5	3,089	9
,, ,, ...	63	3	3,153	0
,, ,, spar veins	9	1	3,162	1
,, ,, ...	27	1	3,189	2
,, ,, shale joints	3	7	3,192	9
,, ,, ...	7	3	3,200	0

The general interpretation of this bore section appears to have been that all the rocks it traversed belong to the St. Bees Sandstone. This view seemed natural, since the band of rocks on which Seascale is situated appears to be the continuation of the sandstones of

St. Bees Head. That the whole of the 3,180 feet of strata belongs to the St. Bees Sandstone is, however, doubtful. One of the most characteristic features of the St. Bees Sandstone is its alternation of posts of red sandstone with beds of shale. Between the depths of 2,072 to 3,200 feet the rocks passed through in the Seascale bore have this character, for they consist of twenty beds of shale and shale partings and twenty beds of sandstone. Two core samples, which I owe to the kindness of Mr. Fleming Smith, one from the top and the other from the bottom of this lower part of the section, are both similar to the St. Bees Sandstone. The upper sample is a typical St. Bees Sandstone with partings of abundant white mica. The precise depth of this sample is not known. Mr. Fleming Smith tells me that it came from between the depths of 1,940 and 2,344 feet; and out of this 404 feet the top 132 feet lies within the thick upper sandstone, and the lower 272 feet belongs to the alternate sandstone-shale series. Judging from the aspect of the rock it probably came from one of the sandstones of the lower 272 feet belonging to the sandstone-shale series.

The specimen from the depth of 3,200 feet I examined microscopically on the chance of recognizing some material which would indicate the source of the constituents. It is a felspathic grit, similar to much St. Bees Sandstone; the section contains numerous rounded grains which have probably been derived from the Penrith Sandstone. As the section shows tourmaline and kyanite, Mr. G. W. Tyrrell kindly extracted some of the heavy residue; he has identified in it abundant zircon, tourmaline, magnetite, and ilmenite, many grains of andalusite, some of which are well rounded, and also particles of staurolite, kyanite, and possibly of cordierite and anatase.

In its microscopic characters the rock agrees with the St. Bees Sandstone; and this list of accessory constituents suggests that the material was derived from south-western Scotland rather than from the Lake District. The rocks on the margin of the Galloway Granite would have supplied the accessory minerals.

Further doubt as to whether all the beds belong to the St. Bees Sandstone is suggested by their great thickness. Goodchild, in one of the latest summaries of the geology of Cumberland, estimated the maximum thickness of the St. Bees Sandstone as 1,800 feet ("Geology" in *The Victoria History of the County of Cumberland*, vol. i, p. 36, 1901); and though it is possible that the formation may have suddenly increased to 3,200 feet, as by the filling up of an ancient valley, any such thickness of the St. Bees Sandstone was not expected when the bore was undertaken, and it justifies doubt as to the identification.

That the upper part of the Seascale bore was not in the St. Bees Sandstone is suggested by the great thickness of continuous sandstone, which, according to the bore record, amounts to 2,047 feet of sandstone interrupted by only a 5 foot seam of red shale. I know of no such occurrence in the St. Bees Sandstone. It is unfortunate that no cores from this upper Seascale Sandstone are available. Mr. Fleming Smith tells me that the cores have been dispersed, and if any specimens could be found there would be no evidence as to their depth. The only evidence available from the bore is the record of the great thickness of this upper sandstone. The reference of 2,047 feet of sandstone, with only one 5 foot band of shale, to the St. Bees Sandstones is at least doubtful; and the possibility that this upper Seascale Sandstone may belong to the Keuper and represent the Kirklinton Sandstone must be considered. The Triassic beds beneath the drifts of Walney Island, 17 miles along the coast south-eastward from Seascale, have been transferred from the horizon of the St. Bees Sandstone to the Keuper.[1] The Keuper appears to be represented along the southern coast of Cumberland by its lower sandstones at Seascale and by its upper marls at Walney Island. If this suggestion be correct, the Keuper Sandstones are much thicker at Seascale than near Carlisle; but such an increase may be reasonably expected approaching the basin that no doubt existed to the west of Cumberland.

The Kirklinton Sandstone is very different in character from the St. Bees Sandstone; and if samples of the upper sandstone from the bore could be found the question could probably be at once settled; and if this note lead to the recovery of any sample of the core from the thick upper sandstone its publication will be well repaid.

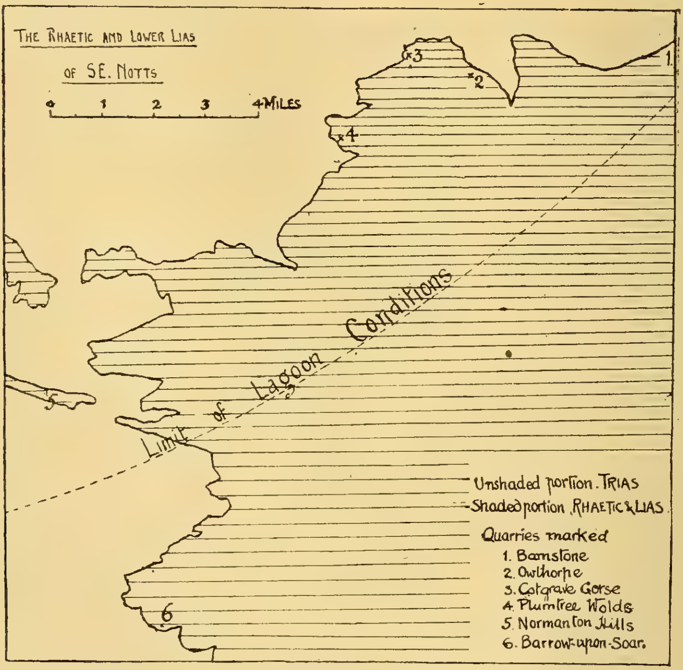
Fortunately, beside the beach at Seascale there is a scar of red sandstone, which is doubtless an outcrop of the upper sandstone of the bores. I owe to the kindness of Mr. Brockelbank, the station-master of Seascale, a collection of specimens from this exposure. The commonest rock is a red friable stone which crumbles readily beneath the fingers, and is a sandrock rather than a sandstone. Some of the specimens are more compact, and are entitled to be regarded as sandstone. In some the material has been cemented by a siliceous cement. Most of the rock is red, but some of it is white or greyish in colour. All the specimens are crowded with wind-rounded grains of quartz, and they have fewer grains of felspar. The specimens received show no layers of white mica. There are many specks stained dark brown by peroxide of manganese; and in two of the specimens some of the quartz grains have regrown into crystalline forms. These characteristics are not those of the St. Bees Sandstone; they occur in both Penrith Sandstone and Kirklinton Sandstone, some hand specimens of which are indistinguishable. The presence of the Penrith Sandstone at this locality is so improbable that of these two formations the Seascale beds would certainly belong to the Kirklinton Sandstone. Microscopic sections cut from three varieties of the rocks from the scar at Seascale show that they are strikingly different from the St. Bees Sandstone, and agree in all essential characters with the Kirklinton Sandstone. This outcrop therefore supports the inference from the bore record that the upper thick sandstone below Seascale belongs to the Keuper, and may be correlated with the Kirklinton Sandstone. The great thickness of the Red Sandstone Series at Seascale is therefore less surprising than if the bore had been begun in the St. Bees Sandstone.

[1] Geol. Surv. England and Wales. Map 4 miles to 1 inch. Sheets 5, 6, 1907.

III.—The Fauna of the Hydraulic Limestones in South Notts.

By A. E. Trueman, B.Sc., University College, Nottingham.

Although numerous papers, principally by the late E. Wilson,[1] describing the beds of the Rhætic and the Lower Lias of Notts, were published while exposures existed along railway cuttings in the south-east of the county, no account of the precise positions of important fossils is to be found. These exposures are now all grass-grown, but the junction of Rhætic and Lias may be seen in a number of quarries where hydraulic limestone is worked, either for cement or for road material. One of the best is at Owthorpe. Those at Cotgrave Gorse,[2] Barnstone,[3] Plumtree Wolds, and Normanton Hills[4] are confirmatory. The layers rich in Foraminifera have been of value in correlating these sections.



Constructed from the Index Map of the Geological Survey, No. 11.

The section at Owthorpe (300 yards S.S.W. of the Lime Kiln Inn) shows the following succession (the names given in brackets are the workmen's terms):—

[1] Q.J.G.S., vol. xxxviii, p. 454.
[2] *Geology of Melton Mowbray and South-East Notts* (Mem. Geol. Surv.), p. 19.
[3] *Jurassic Rocks of Britain*, vol. iii, p. 172.
[4] *Geology of Melton Mowbray and South-East Notts*, pp. 17, 18.

		ft.	in.	
Beds with *Planorbis*.	Yellow calcareous clay .	1	0	Worn Saurian vertebræ, *Lima*.
	Pale flaggy limestone (Skerries)		10	*Psiloceras planorbis*, *Amm. Johnstoni*.
	Coarse clay . . .		3	Echinoid spines, Ostracods, fish-scales, *Lima*, Belemnites.
	Yellow earthy nodular limestone with 'spine-bed' at top		6	*Ps. planorbis*, *Ostrea*, *Lima*, *Modiola minima*, *Turbo* sp.
	Dark calcareous shale .		2	Spines, Fish-teeth, Foraminifera.
	Blue-hearted earthy limestone		2	*Ps. planorbis*, *M. minima*.
	Shale		9	Spines, Ostracods, fish-teeth, Foraminifera.
Beds without *Planorbis*.	Dark, blue-hearted limestone		3½	*Pecten* sp., *Lima*, *M. minima*.
	Shale . . (Twins)		2	Spines, Ostracods, many Foraminifera (*Nodosaria*).
	Limestone as above		3	*M. minima*.
	Shale	2	0	Foraminifera, spines, Ostracods.
	Blue, wavy-banded, fine-grained limestones, with shell bands near top	2	0	*Ostrea irregularis*, *O. liassica*, *Pleuromya crowcombei*, *Avicula cygnipes*, *M. minima*, spines.
	Fine-grained, well-laminated, blue calcareous mudstones	1	3	*M. minima* and Ostracods, rare; worm bores.
	Fine dark-blue limestone .		5	*M. minima*, rare.
	Mudstones, as above . .		2	Ostracods, rare.
	Variable limestone bands .		3	*Ostrea*, rare; *M. minima*.
	Mudstones, as above . .	2	0	*M. minima*.

Soft blue clay, Rhætic, below level of working.

Similar beds without *Planorbis* are described as "pre-*Planorbis* beds" by L. Richardson in the neighbourhood of Cheltenham.[1]

A comparison of the above section with that at Barrow-upon-Soar (in North Leicestershire, 11 miles distant) is instructive. While in the section just described about 8 feet of beds occur between the Upper Rhætic and the lowest beds with the zone fossil, there *Psil. planorbis* occurs also in beds which immediately succeed the Upper Rhætic.

As shown by the following table, the beds without *Planorbis* at Owthorpe (and also at the other exposures mentioned previously) are of Liassic age, for the fauna differs only slightly from that of the overlying beds with *Planorbis*.

	Upper Rhætic.	Beds without *Planorbis*.		Beds with *Planorbis*.
		Lower.	Upper.	
Ostrea liassica . .		r.	C.	c.
O. irregularis . .		r.	C.	c.
Lima gigantea .		r.	c.	C.
Saurian remains .			r.	C.
Pecten sp. . .			C.	C.
Foraminifera . .		r.	C.	C.
Echinoid spines .		r.	c.	C.
Pleuromya crowcombei		r.	C.	
Avicula cygnipes .			r.	
Estheria minuta .	c.			
Modiola minima .	r.	C.	C.	C.
Cytheridea sp. .	r.	C.	c.	c.

r. rare; c. fairly common; C. very common.

[1] *Geology of Cheltenham*, pp. 21–36.
[2] *Geology of Melton Mowbray and South-East Notts*, p. 29.

Moreover, the fossils found at Barrow are on the whole the same, and show a similar distribution, so that the bottom beds at Owthorpe and Barrow must be homotaxial. This being the case, it is evident that the beds at Owthorpe can hardly be called "pre-*Planorbis*", for at the time of their deposition *Planorbis* was in existence a few miles away.

The character of the fauna in the lowest beds of all in the Owthorpe district suggests a possible explanation of the absence of *Planorbis*, for it is very impoverished, the only fossils being *Modiola minima* and Ostracods (*Cytheridea ellipsoidea*, Jones). This type of fauna is characteristic of lagoon phases, for, according to Mr. Dixon, these are "all distinguished in places by exceedingly fine-grained calcite mudstones with an impoverished fauna of Lamellibranchs (especially *Modiola*), Ostracods, and *Spirorbis*. A certain amount of terrigenous material, mud, and fine sand is found in them all".[1]

Confirmatory evidence of such conditions in the Owthorpe district is seen in occasional worm bores and traces of ripple-marks. Further, the occurrence of insect-remains at Barrow, indicating the proximity of land, supports rather than opposes this view.

With regard to the underlying Rhætic beds, it might be here recorded that the top bed of Rhætic limestone at Cotgrave Gorse is cracked, the cracks being filled with calcite. The upper edges of the blocks often show a pitted and bored appearance, which may in some cases have been caused by worms. A similar bed has been described near Bath, and is there called the Sun Bed.[2]

I should like to express my thanks to numerous friends who at various times have assisted me in the field, and to Professor H. H. Swinnerton, of University College, Nottingham, whose inspiration and help are mainly responsible for this little paper.

IV.—The Intrusive Rock of Marston Jabet, Nuneaton, Warwickshire.

By Alfred Brammall, B.Sc. (Lond.), F.G.S., Assistant Director of Education, Bury, Lancs.

(PLATE VI.)

1. *Introduction and References to Literature.*

The intrusive rocks of Marston Jabet and Chilvers Coton, though probably of quite minor importance, have been rendered noteworthy by the variety of opinions held regarding their true position in a scheme of rock classification. This is especially the case as regards the rock quarried at Marston Jabet. Thus Allport[3] comments upon certain remarkable features distinguishing this rock, which, however, seems to be covered by his general statement that the intrusive rocks of the Warwickshire Coalfield are for the most part ordinary diorites. Rutley[4] concurs in the opinion expressed by

[1] Q.J.G.S., 1911, p. 571.
[2] *Geology of Wellington and Chard* (Mem. Geol. Surv.), pp. 27, 28.
[3] Q.J.G.S., vol. xxxv, p. 637, 1879.
[4] Geol. Mag., 1886, p. 562.

Allport. Watts[1] calls attention to the lamprophyric aspect of the rock, which he terms a camptonite; and with this description Harker[2] agrees. Hatch[3] admits the lamprophyric features and incidentally refers to the lack of recorded analyses.

The conclusions arrived at in this paper are based upon a detailed examination of the rock in situ, upon a microscopic investigation of a large number of thin sections, and upon a partial chemical analysis of the prevalent rock type.

2. *The Intrusive Character of the Marston Jabet Rock.*

There is no question as to the intrusive character of the rock; for completeness, however, the evidence for intrusion is set out below in some detail, the features described being those observed at the quarry in August and December, 1912.

The country rock is Coal-measure shale horizontally bedded. In the middle of the quarry is a horizontal platform of shale from above which igneous rock has been removed. At the quarry face the latter rock extends for several feet below the plane of the middle platform; it is therefore clearly transgressive.

At the north-east end the quarry face is a pillar of laminated shale continuous with the platform below and extending upwards to the ground level. The shale is injected with narrow veins and strings of 'white trap' along bedding- and joint-planes. The veins and strings are frequently transgressive, and may also be traced into the main mass of igneous rock.

To the east and south long slabs and smaller lenticular masses of shale are seen embedded in the igneous rock. In the southern face two constant horizons of igneous rock are separated by a shale band 2 feet thick; both the shales and the igneous rock sag slightly.

The shale bordering the tramway incline is baked a brick red for a distance of about 2 feet above the igneous rock. Shale at the contact is usually porcellanized for a distance of one inch, and indurated for a greater, though variable, distance beyond. *Lit-par-lit* injection of the shale is frequent. The texture of the igneous rock near its junction with the shales is compact and basaltic, whereas in the centre of the mass it is crystalline.

The rock is obviously a sill-like intrusion in the shale, which, however, appears to have suffered little or no disturbance.

3. *Macroscopical Features of the several varieties of the Intrusive Rock.*

The prevalent rock is greenish-grey crystalline, of fine or medium texture, having a distinctly dappled or mottled appearance when wet, owing to concentrations of hornblende and of felspar as minute but discrete clots—glomeroporphyritic structure, which is assumed by both hornblende and felspar. Pyrites in specks and irregular strings is very abundant.

The mottled variety passes insensibly into a more homogeneous, finely crystalline rock, with the aspect of the Nuneaton and Atherstone 'diorites'. Both the varieties noticed effervesce slightly on

[1] Proc. Geol. Assoc., vol. xv, pp. 394–96, 1897.
[2] *Petrology for Students*, 1908 ed., p. 157.
[3] *Text Book of Petrology*, 1909 ed., pp. 329–30.

treatment with dilute hydrochloric acid, owing to the presence of calcite in the rock-mass.

Another variety, occurring as a selvage in contact with the shale, is a dark-grey compact rock, often banded, but otherwise of basaltic aspect, though no crystals are visible even on examination with the lens. The material forming the veins and strings intrusive in the shales is an earthy substance with the appearance, texture, and 'feel' of hardening putty.

4. *Detailed Petrological Description.*

The felspar is mainly plagioclase, which forms slender idiomorphic prisms up to $\frac{1}{10}$ inch in length, usually less, showing between crossed nicols broad but inconstant twin laminæ of the albite type, occasionally combined with Carlsbad and pericline twinning; an extinction angle of 27°–29° points to labradorite of basic composition. The well-individualized albite laminæ of the middle of the felspar prisms are commonly flanked by a narrow marginal band, the extinction axis of which appears to traverse the band from side to side as the stage is rotated—an optical feature due to zonal variation in chemical composition. Orthoclase is a very subordinate constituent of a scanty granular ground-mass.

The felspar has a pronounced yellow-brown tint due to iron staining, and has undergone considerable alteration, resulting in the development of granular calcite and epidote, aggregated mainly in the interior. The alteration has only slightly obscured the definition of the albite laminæ—the contour of the crystal not at all.

The prisms form an open framework, and are frequently interpenetrant at the nodes, where they tend to group themselves radially after the manner of the glomeroporphyritic aggregates common in intrusive and volcanic rocks. This framework, together with hornblende, calcite (in plates or granules), a little granular orthoclase, and rather conspicuous grains of magnetite, is embedded in a nearly colourless or pale-green serpentine associated with subordinate patches of a greenish dichroic substance referred to chlorite.

In the normal type of the rock the felspar prisms may be enclosed in hornblende; in some varieties the two minerals interlock along a sinuous or serrated line, a portion at least of the hornblende having been fluid at a stage when the crystallization of the felspar was incomplete. In yet another variety the hornblende is wholly idiomorphic and independent of the felspar.

Hornblende is very abundant as a dark-brown variety which, when unaltered, is quite transparent and shows intense brown absorption. Often, however, it is so dark as to be almost opaque, suggesting a somewhat advanced stage of alteration. The mineral is conspicuously idiomorphic, giving the usual lozenge-shaped basal sections (acute angles truncated by the clinopinacoid traces) and long prismatic sections. Twinning on the orthopinacoid is common. Hornblende may enclose plagioclase prisms ophitically, or may be conjugate with felspar along a straight, curved, or serrated junction line, or may be an entirely independent constituent. All stages of alteration to serpentine are observable; the serpentine either merely pencils out the cleavages in basal and prismatic sections; or it occurs as coarse irregular ropes traversing the crystal plates in directions roughly parallel to the cleavages; or the original hornblende has been reduced to a meagre skeletal framework embedded in serpentine.

As the opaque brown masses, hornblendic in colour, were suspected to be, in part at least, limonitic, the cover glass of a section was removed, the section cleansed of balsam, and a drop of strong hydrochloric acid applied to the brown mass. In a very few seconds the drop had become coloured a distinct yellow, as shown on its absorption by white blotting-paper, thus proving the presence of iron in some very soluble form in the brown mass, which was therefore composed partly of limonitic matter.

The abundant development of calcite plates in close association with serpentine and limonite suggests its derivation from hornblende rich in lime as well as magnesia, and therefore of the 'basaltic' variety. Relics retaining parallel cleavage traces in single system (i.e. sections more or less nearly in the prism zone) give nearly straight extinction with reference to the cleavage traces. (Pleochroism: a = straw or pale yellow; β or γ = light brown or dark brown.) Narrow strips of a transparent substance, with recognizable cleavage traces, very pale yellow in ordinary transmitted light, and showing intense brown absorption in plane polarized light, appear to be unaltered portions of original hornblende which has suffered bleaching.

The decomposition of the hornblende appears to have proceeded in two different ways—either (*a*) the whole mineral has altered by hydration to serpentine; this is the prevalent method; or (*b*) the magnesia alone has separated from the hornblendic molecule to form serpentine; the lime has formed calcite (as plates and granules) or epidote (as granules), the residual iron as the hydrated oxide retaining the form of hornblende.

In support of the latter suggestion it may be stated that the serpentine contiguous with opaque hornblende relics is usually only very pale green owing to its low iron content, whereas the colour of the serpentine which has originated by method (*a*) is always a pronounced green or yellow-green.

The proportion of serpentine is fairly constant, even when definite indications of original olivine are absent; moreover, it shows a characteristic fibrous or 'bladed' structure under crossed nicols; the major portion, at any rate, of the serpentine may be referred with confidence to hornblende.

The murky-grey colour and complete opacity of much of the limonite suggest admixture with leucoxene representing the titanium of the original hornblende molecule. Some leucoxene is certainly derived from the alteration of titaniferous magnetite.

Rounded or elliptical patches of serpentine showing the 'mesh' structure under crossed nicols occur embedded in the hornblende relics, or very rarely in the felspar; they appear to represent original olivine, very subordinate in quantity. Olivine is probably also represented in the serpentine of the base. The quantity of olivine present is somewhat variable and always small.

Magnetite is abundant in some sections, and present in all. It is titaniferous, as indicated by a greyish opaque outgrowth of leucoxene.

In more than a score of sections examined no augite or other pyroxenic material was observed. Mica is wholly wanting. Apatite is conspicuous as needles, from ·025 mm. to ·075 mm. in length, embedded in the other constituents. Pyrites in granules up to ·3 mm. in length is also a notable accessory.

5. *Discussion of the Systematic Position of the several Varieties.*

Typically the felspar and hornblende show a marked tendency to idiomorphism. The low degree of mutual interference shown by the felspar prisms in particular, the almost total absence of the 'granitic', and the prevalence of the 'glomeroporphyritic' structure are incompatible with diorites. On the other hand, these features may be either hypabyssal or volcanic; the absence of a glassy base eliminates the latter as a probability, while the ophitic relationship of the felspars and hornblende, and the basic character of the former (labradorite), recall the structure of the typical dolerites, and the coming in of olivine suggests analogy with the olivine dolerite type. Dolerites, however, are typically pyroxenic, and in this rock pyroxenes appear to be wholly wanting, and no secondary amphibole, which might have been referred with reason to primary augite, was observed. The idiomorphism and the primary character of the hornblende are incompatible with the type dolerites.

On the other hand, individual femic clots may monopolize the whole of a field visible under the microscope; in such case the subordinate amount of the felspar visible, the serpentinous pseudomorphs of olivine, occurring as pœcilitic inclusions in the hornblende, recall the picrites; but even this resemblance is illusive, for the field adjoining such a femic patch may be entirely devoid of hornblende and even comparatively free from its serpentinous decomposition products. Moreover, the rock as a whole must be excluded from the picrite group by reason of the high proportion of felspar and the very small amount of olivine present.

The idiomorphism and porphyritic aspect of the hornblende, considered together with other hypabyssal features, admit the rock without question into the lamprophyre group. The red-brown hornblende, the essential absence of free silica, the conspicuous apatite and titanium content link the rock with the type camptonite of Campton Fells, N.H., and the classification of the main rock-mass as a camptonite is open to little objection. The olivine, too insignificant in quantity for the picrites, ranks as a noteworthy accessory when the rock is regarded as a camptonite. In the typical camptonite, however, hornblende recurs as microlites in the base. This is not the case in the Marston Jabet rock.

The camptonite rock forms the bulk of any one of the sheets of the intrusive mass. The olivine is more abundant in the centre of the mass than near the margin, and it is in the centre that the nearest approach to a picritic facies was observed.

A partial analysis of the mottled rock was carried out in the laboratory of the Bury Technical School in consultation with Mr. G. M. Norman, B.Sc., F.I.C., A.R.C.S., and the results obtained, together with recorded analyses (cited by Hatch) of other camptonites and of a well-known picrite, are set out below:—

	Camptonite (Marston Jabet).	Camptonite (Ardmuchnish).	Camptonite (Orkneys).	Picrite (Blackburn–Bathgate Hills).
	%	%	%	%
SiO_2	44·75	42·22	39·13	44·73
Fe_2O_3	15·15	4·74	7·33	4·85
FeO	(estimated as Fe_2O_3)	6·18	8·13	6·61
Al_2O_3	16·26	10·62	11·38	11·89
MgO	11·72	8·68	8·64	10·77
CaO	7·35	14·80	11·77	7·69
Na_2O	not estimated	2·46	2·47	2·77
K_2O	not estimated	1·41	1·93	·89
TiO_2	not estimated	2·49	4·02	1·53
CO_2	not estimated	3·57	2·41	—
H_2O	not estimated	1·66	2·87	7·64
P_2O_5	0·22			
Other constituents		1·59	0·42	1·06
		100·42	100·50	100·43

The selvage rock, when examined in thin section, presents the ordinary features of an andesitic basalt and calls for no special description.

Very little absorption of the shale by the igneous rock has taken place at the junction, and the absorption zone is probably not more than $\frac{1}{8}$ in. wide. In sections showing the igneous rock and the shale in contact, the former near its junction with the latter is very dark, almost black, and quite opaque, due probably to the presence of free carbon derived from the shale, on the solution of a very limited amount of its alumina. The frequent occurrence of a pencil-like vein of calcite crystals marking the contact plane indicates that the latter became a plane of discontinuity after the intrusion, and, therefore, that the intrusion was accompanied by a negligible amount of chemical reaction between the igneous mass and the shales.

The earthy material forming the veins and strings which penetrate the shales recalls the 'white trap' (kaolinized basalt) described by Geikie[1] as penetrating Lower Carboniferous shales in the Lowlands of Scotland.

6. *The Alteration produced in the Shales.*

In the main the alteration is of the low grade and small extent usual for similar intrusions; but a microscopic investigation of certain portions of these shales in thin section reveals the presence

[1] Q.J.G.S., 1892, Pres. Address, p. 136.

of embryonic crystals, the features of which so closely approach those of chiastolite as to render the identity highly probable. This 'unconventional' occurrence of chiastolite will be fully discussed in the May Number of the GEOLOGICAL MAGAZINE.

EXPLANATION OF PLATE VI.

STRUCTURAL TYPES.

FIG. 1.—A dioritic facies—but with pronounced hypabyssal features. Hornblende relics, of somewhat raggy outline, but tending to idiomorphism; cleavages pencilled out in serpentine. Base made up of much altered plagioclase as prisms and irregular plates, the clear interspaces being filled with chloritic and serpentinous matter; some calcite; abundant apatite; some titaniferous iron-ore (with leucoxene); grains of pyrites; and a little granular epidote in plagioclase, of which it is a decomposition product.

FIG. 2.—A picritic facies. The proportion of plagioclase is much lower than for No. 1; it occurs not only in the base but as minute prisms enclosed ophitically in hornblende. Clear patches represent crystals of original olivine now altered to serpentine, which also envelops plates and granules of calcite. Circular and elliptic 'lakes' of serpentinous matter enclosed pœcilitic fashion in the hornblende appear to represent original olivine.

FIG. 3.—A coarse lamprophyric facies (camptonite). The idiomorphic hornblende is, in the main, phenocrystal, though the presence of small felspar prisms as enclosures in the hornblende is (for lamprophyres) an anomalous feature. This ophitic relationship of the felspar to the hornblende recalls the structure of typical dolerites (the hornblende playing the rôle of pyroxene in dolerites); and it may be that the fluid intrusive, potentially doleritic, has crystallized at a temperature too low to promote the formation of pyroxene, i.e. at a temperature at which hornblende can form and remain stable; in this sense the camptonite may be an abortive dolerite. But the phenocrystal aspect of the hornblende (with other hypabyssal features) insistently recalls the lamprophyres: the rock must be regarded as a variety of camptonite.

FIG. 4.—A fine-grained hornblende lamprophyre (closely related to the coarse camptonitic facies), in which the idiomorphic hornblende occurs as minute laths.

V.—THE ORIGIN OF LIMESTONE.

By H. WARTH.

ALTHOUGH the calcium oxide and magnesia of sedimentary limestone and dolomite must all be derived from pre-existing igneous rocks, it is not so easy to trace the origin of the necessary carbon dioxide. The solidified igneous rocks contain mere traces of free carbon dioxide and of calcite. During their weathering carbon dioxide is taken up from the atmosphere, replacing the silica of calcium silicate and magnesium silicate minerals, and forming the carbonates. Now, however, the quantity of carbon dioxide retained in the atmosphere is exceedingly small. It is difficult to credit, for instance that a layer of coal, $1\frac{1}{2}$ millimetres thick, covering the surface of the globe, on being burnt would yield as much carbon dioxide as the entire atmosphere now contains. A similar layer of limestone containing an equivalent amount of carbon dioxide would have a thickness of 5 millimetres. This is out of all proportion compared with the mighty beds of limestone and dolomite now forming part of the earth's crust. Nor would the carbon dioxide

A. Brammell, Photo. Bale, Sons and Danielsson, Ltd.

Sections of INTRUSIVE ROCK of Marston Jabet, near Nuneaton, Warwickshire.

of the sea avail anything. It exceeds in quantity that of the air, but is still at the most equivalent to 7 centimetres of limestone covering the earth's surface. Now the existence of animal life throughout the sedimentary era implies that from the earliest times the composition of the earth's atmosphere cannot have differed very materially from the present one. Yet as carbon dioxide has been continuously taken up by weathering igneous rocks, and also by the production and storage of mineral, coal, etc., there must have been a continuous renewal of the carbon dioxide contents to maintain an equilibrium. The distribution of limestone throughout the whole sedimentary era, and the alternate occurrence of coal of different ages, leave no doubt that there has been a regular accession or renewal of carbon dioxide from first to last. The only question we have to answer is where this carbon dioxide was derived from.

The amount of carbon dioxide as calcite and in the free state in the solidified igneous rocks is far too little for the above purpose, but there is ample evidence of a continuous supply by exudation from deep-seated parts of the earth's crust. The gas issues either by itself at isolated points in smaller quantity, or else in larger bulk in certain volcanic regions. Much of it appears also in solution in mineral springs. The possibility of a continuous supply is demonstrated by the fact that fiery liquid lava is known to give up carbon dioxide on its appearance at the earth's surface. It is thus clear that the cooling and solidification of igneous rocks may be accompanied by an issue of carbon dioxide gas, and this issue will be very regular, as the process of cooling is also regular and practically constant. This, then, is the source from which the atmosphere is supplied with carbon dioxide, which is all the time utilized in the production of limestone and dolomite, coal, bitumen, etc.

To confirm this explanation it would be necessary to collect statistics, firstly of all the stores of limestone on the earth's surface, and secondly of the approximate issue of carbon dioxide. It would be no small task to procure such data with any degree of accuracy. Meanwhile a very rough estimate might be made, or should we call it a guess, to serve the purpose of a test. If we assume the accumulated sedimentary limestone of the earth's outer crust to equal a bed 50 metres in thickness covering the land surface of the globe, and if we fix the duration of sedimentaries containing organic remains (animal) at fifty million years, we can easily calculate the uniform issue of carbon-dioxide gas per second. This uniform issue of gas equals at 760 millimetres pressure 2,500 cubic metres.[1] Considering the size of the earth we may rest satisfied that this amount is at all events of the right order of magnitude, and that the above hypothesis stands on a good foundation. We have thus before us one more of the wonderful provisions for the persistent development and maintenance of plant and of animal life on the globe.

[1] I find records in Bishop's *Elements of Chemical and Physical Geology* showing that the mineral springs at Cannstatt yield one quarter of a cubic metre of carbon dioxide per second.

VI.—The Principle of Saturation.

By Alexander Scott, M.A., B.Sc.

IN Professor Shand's reply [1] to my criticism [2] of his original paper [3] on the application of the principle of saturation with respect to silica in the classification of igneous rocks, some points arise which make it clear that he has misunderstood me in several particulars. In the beginning of my paper, it was explicitly stated that what was to be considered was (1) whether the principle, as enunciated by Professor Shand, could be extended to minerals other than the silica ones (quartz, tridymite, etc.), the felspars and the felspathoids, and (2) whether the criterion whereby the rock minerals were divided into the two groups of saturated and unsaturated was sufficiently exact. The criterion used was that of "the observed facts of distribution", and any mineral which was found coexisting with quartz or some other form of silica in igneous rocks was said to be saturated, while those which did not occur along with quartz were said to be unsaturated. Correspondingly, rocks which consisted entirely of minerals of the former type were classed as saturated, those consisting of mixtures of the two types as part-saturated, and those consisting solely of the second type as unsaturated. I endeavoured to show that the rock-forming minerals cannot be satisfactorily divided into two classes in this empirical fashion, without any consideration of the cooling-histories of the individual rocks in which the minerals may be found.

One of the specific points discussed was the possibility of the coexistence of quartz and olivine in an igneous rock, and I indicated two ways in which free silica (other than xenolithic) might exist *in small quantities* in a part-saturated or unsaturated rock. What was suggested was, that under certain particular conditions metasilicates might dissociate into orthosilicates and free silica; while, under other conditions, silica might be set free by the hydrolytic action of water. No attempt was made to suggest that the coexistence of the two minerals was general or that the circumstances favouring it were other than exceptional, and hence the instances of the Kilsyth–Croy sill,[4] Garabal Hill,[5] etc., are not relevant to the point at issue. The work of Anderson and Bowen [6] was quoted merely as a verification of the idea that dissociation was possible. These authors, however, have pointed out that this dissociation, despite the fact that it takes place above 1557°, has a distinct petrological bearing. Again, olivine is seldom the pure magnesium orthosilicate, but generally contains a considerable amount of the corresponding ferrous salt. If, as is probable, the latter also undergoes dissociation near its melting-point, silica will be set free at temperatures much below 1557° and well

[1] Geol. Mag., Dec. V, Vol. X, pp. 508–14, 1913.
[2] Ibid., Dec. VI, Vol. I, pp. 319–24, 1914.
[3] Ibid., Dec. VI, Vol. I, pp. 485–93, 1914.
[4] Geol. Mag., Dec. V, Vol. VI, pp. 299–309, 1909.
[5] Ibid., Dec. V, Vol. X, pp. 499–508, 1913.
[6] *Amer. Journ. Sci.* (4), xxxvii, pp. 487–500, 1914; *Zeit. für Anorg. Chem.*, lxxxvii, pp. 283–99, 1914.

below the temperatures of crystallization of many igneous rocks, since the melting-point of fayalite is given by Vogt[1] as 1065°, and fayalite and forsterite form a continuous series of solid solutions conforming to Roozeboom's Type I.[2]

There is a very considerable amount of evidence against Professor Shand's view that the compound $Fe\,Si\,O_3$ cannot exist under any conditions realized in nature. Thus an amphibole, grünerite, consisting of almost pure $Fe\,Si\,O_3$, has been described from Collobrières in France.[3] Hypersthene consists of an isomorphous mixture of $Mg\,Si\,O_3$ and $Fe\,Si\,O_3$, as the two salts form a series similar to the corresponding orthosilicates,[4] and hence both must exist in a free state. The occurrence of $Fe\,Si\,O_3$ in the double salt hedenbergite, $Ca\,Fe\,Si_2O_6$, also points to its free existence, in the liquid condition at least. The rarity of crystals of pure $Fe\,Si\,O_3$ is probably to be explained by the fact that rocks with $Fe\,O$ generally contain $Mg\,O$ as well, and by the tendency of $Fe\,Si\,O_3$ to form double salts and to enter into solid solution not only with enstatite but also with monoclinic pyroxenes. The occurrence of fayalite in the lavas of Pantellaria[5] is best explained by the dissociation hypothesis, the unstable form persisting as the result of the undercooling to which these rocks would be liable owing to the rapid fall in temperature on extrusion.

With respect to the felspathoids, the remarks in my paper regarding the reaction

$$\text{kaliophilite} + \text{orthoclase} \rightleftharpoons \text{leucite}$$

referred to crystallization from the liquid state, and no mention was made of the transformation, in the solid state, of leucite to pseudo-leucite. What was stated was that a rock, which under some conditions might crystallize as a leucite rock, would under other conditions form a nephelite-felspar rock. That this case is very pertinent to the question at issue, is shown by the following example. A leucitite or leucite-basalt, in which the predominant minerals are leucite and olivine, would have to be classed as unsaturated. A rock of the same chemical composition could also solidify as a nephelite-felspar-olivine rock, which would be classed as part-saturated. The two rocks would therefore be widely separated in classification, although, petrologically, they would have many affinities, and would exhibit the same tendency to react with any sediments with which they were in contact. The same anomalies appear when analcite is considered in place of leucite.

The chief point in objecting to the garnets being classed partly as saturated and partly as unsaturated is their probable origin under particular conditions of temperature and, more especially, pressure. The fact that most garnets break up on fusion and recrystallize as mixture of other minerals is in favour of this, as is

[1] *Die Silikatschmelzlösungen*, ii, p. 66, 1904.
[2] Ibid. i, p. 152, 1903.
[3] *Comptes Rendus*, xxiv, p. 784, 1847; Bull. Soc. Min. Franç., ix, p. 40, 1886.
[4] Vogt, loc. cit., ii, p. 112.
[5] *Journ. Geol.*, xxii, pp. 16–27, 1914.

also their comparative restriction to metamorphic rocks. Shepherd and Rankin[1] found that grossularite broke up on melting to give a mixture of anorthite, pseudo-wollastonite, and gehlenite (?), and that it did not appear on the fusion surface of the ternary system $CaO - Al_2O_3 - SiO_2$. Of the three garnets which commonly occur in igneous rocks, pyrope is always a product of early separation from the magma, and its probable instability at lower temperatures and pressures is shown by the frequent occurrence of celyphite-borders. Thus Rosenbusch says[2]: "Er [Mhra] nimmt an, dass der in grösserer Tiefe gebildete Pyrop bei Abnahme des Druckes wahrend die Aufsteigens des Magmas mit dem Olivin in Reaktion trat." Its occurrence in a lava does not militate against its crystallization under plutonic conditions, as such rocks are generally considered to have two periods of crystallization, one 'intratelluric' and the other 'effusive', the formation of pyrope belonging to the former.

With regard to melanite, it seems that the chemical factor which determines its occurrence is not so much the amount of silica as the titanium-content, since rock-forming melanites are generally rich in the latter element. Thus, the garnet of the nephelite dolerite of Oberweisenthal contains 10·84 per cent of TiO_2.[3] Again, in the Borolan complex, melanite seldom occurs along with primary sphene, which, however, tends to increase as the melanite fails. The latter also alters readily to secondary sphene.[4] This fact points to the instability of melanite, and indicates that under other conditions a mixture of sphene and, probably, pyroxene, would have taken its place. Further, Weinschenk states that titanium free-lime garnet occurs exclusively as a secondary product of volcanic activity.[5] In some of the occurrences of spessartite it has been shown that the mineral is of pneumatolytic origin,[6] while in practically the only synthesis in which the composition was verified by analysis a mixture of hydrogen and steam was used as a catalyst.[7]

Similar objections can be raised to many other minerals being classed as saturated or unsaturated merely on the strength of their field occurrence. If the variability of composition in the amphibole group is an insuperable barrier to the correlation of mineralogical and chemical composition, it is likewise a barrier to the saturation classification. Numerous amphiboles and pyroxenes have been described containing an amount of silica insufficient to 'saturate' the bases present, and this has led to the postulation of such molecules as $R''Al_2SiO_6$, which can obviously take up more silica. Whether these hypothetical molecules actually exist or not, the fact remains that some of the minerals included in the pyroxene and amphibole groups are deficient in silica.

[1] *Journ. Ind. Eng. Chem.*, iii, No. 4, p. 10, 1911.
[2] *Mikroskopische Physiographie*, 4th ed., i, ii, p. 25, 1905.
[3] Rosenbusch, *Elemente der Gesteinlehre*, 3rd ed., 1910, p. 458.
[4] Shand, Trans. Edin. Geol. Soc., ix, pt. iii, p. 205, 1909; pt. v, p. 386, 1910.
[5] *Zeit. Kryst. Min.*, xxv, p. 375, 1895.
[6] Penfield & Foote, *Amer. Journ. Sci.* (4), iv, p. 105, 1897.
[7] Gorgeu, *Ann. chim. phys.* (4), iv, pp. 515–56, 1883; *Compt. Rend.*, xcvi, p. 1303, 1883.

While so many obvious difficulties stand in the way of the determination of the degree of saturation of the rock-minerals, there are fully as many when the rocks themselves are considered. The method, in common with all purely mineralogical methods, fails when, not only vitreous, but all aphanitic rocks are concerned. Many minerals of fundamental importance, such as nepheline and analcite, are often difficult to recognize in the groundmass of such rocks and can sometimes be detected only by a chemical analysis.

Again, the operation of the principle of solid solution, which is probably the most important physical-chemical factor in determining what minerals crystallize from a magma, often results in the development of 'hidden' molecules. Many minerals can take up free silica or other silicates in solid solution; for example, most of the extant analyses of nephelite show an excess of silica over that required for the formula $Na\,Al\,Si\,O_4$,[1] this excess being due to the presence of an isomorphous mixture, probably of albite and nephelite. The existence of such 'hidden' molecules is of great importance when the possibility of a rock reacting with the surrounding strata is considered. Such reaction depends on the degree of 'normative' saturation, which can in many cases only be determined by chemical means.

If the existence of a small modal amount of an unsaturated mineral is to be considered sufficient evidence to classify a rock as part-saturated, certain anomalies may arise. It is conceivable that the amount of free silica in solid solution might be sufficient to make up the deficiency in the unsaturated mineral, thus rendering the rock normatively saturated but modally part-saturated. From the petrological point of view, certain accessory minerals would tend to assume an exaggerated importance, with the result that, not only would anomalies arise in the classification of transition types, but also petrological affinities would be obscured. The difficulties introduced by this want of elasticity can be easily exemplified by a consideration of a few such transition types.

Some of the rocks, which have been described as pulaskite, have greater affinities with the monzonites than with the nephelite syenites, yet the presence of a trace of nephelite would necessitate their classification with the latter. On the other hand, an umptekite[2] may contain no apparent nephelite and yet be more closely akin to nephelite-syenite than to any other type. Some of the basaltic mugearites of the Kilpatrick Hills are olivine-free,[3] yet they have many affinities with the Jedburgh basalts, into which they grade by the appearance of labradorite and olivine. As Iddings has pointed out,[4] a minette can have the same composition as a leucite basalt, olivine and leucite being the high-temperature products of a magma which, if it has crystallized under plutonic conditions at a lower temperature, would have resulted in a mixture of orthoclase and

[1] Cf. Foote & Bradley, *Amer. Journ. Sci.* (4), xxxi, pp. 25–32, 1911.

[2] Rosenbusch, *Mikroskopische Physiographie*, 4th ed., ii, i, pp. 151–4, 1905.

[3] Tyrrell, Trans. Glas. Geol. Soc., xiv, p. 238, 1912.

[4] Quoted by Harker, *Science Progress*, vol. ii, No. 6, p. 242, 1907. See also Fouqué & Michel-Lévy, *Synthèse des minéraux et des roches*, 1882, p. 77.

biotite. Here we have a case where the volcanic representative of a saturated plutonic rock is a highly unsaturated rock.

A continuous sequence, with but little variation in composition, is often observed, from pyroxenite through wehrlite to dunite; nevertheless, olivine-free pyroxenite would have to be sharply discriminated from both wehrlite and dunite. The same remark applies to the allivalite-dunite series. Such examples, where the local, and sometimes apparently accidental, occurrence of an unsaturated mineral might widely separate closely related rocks, could be multiplied indefinitely. Enough has been said to show that the Principle of Saturation, applied in such an empirical fashion, is not sufficiently elastic, and also that it tends to obscure petrological affinities as well as the relative petrological values of minerals.

With regard to other classifications, there are several alternatives to Professor Shand's other than the silica-percentage one and Winchell's. Thus Tyrrell[1] has recently indicated the possibilities of a quantitative modal system. Many of the difficulties of such a system would disappear were more analyses of the groundmass of aphanites available, while in addition the 'typical' composition of constituent minerals could also be utilized. This author has also pointed out that one reason of Iddings' failure to correlate chemical with mineralogical composition is the fact that very few modes have been determined. At the present day any biological classification which was not primarily based on the phylogeny and ontogeny of species would not be considered. In view of the recent great developments in petrology, there seems no good reason why these two factors should not also be fully utilized in rock-classification. As Harker has said, "There are those who would have us abandon in despair all endeavour to place petrography on a genetic basis and fall back on a rigid arbitrary system as a final solution of the difficulty. This would be to renounce for ever the claim of this branch of geology to rank as a rational science."[2]

VII.—The Fossiliferous Molluscan Deposits of Wexford and North Manxland.

By Alfred Bell.

The notes by Professor Grenville A. J. Cole & Mr. T. Hallissy on the Wexford Gravels,[3] and those by Dr. F. Cowper Reed on the Manxland shells in the Strickland Collection at the Sedgwick Museum, Cambridge,[4] published in last year's Geological Magazine, will be welcomed by geologists as drawing attention to an interesting but too long neglected subject. The principal object of this paper is to point out the faunal relations of the deposits in question to each other, and wherein they differ from those of the neighbourhood which are usually grouped with them, including the high-level shelly drifts of Moel Tryfaen, Macclesfield, Gloppa, and the Wicklow

[1] *Science Progress*, ix, No. 33, pp. 60–84, 1914.
[2] Rep. Brit. Assoc. Portsmouth, 1911, pp. 380–1.
[3] Geol. Mag., pp. 498–509, 1914.
[4] Op. cit., pp. 544–5, 1914.

Mountains, the limestone drifts and shelly clays of Ireland from Ballybrack Bay to Glenarm, and the stony or boulder clays of Cheshire and Lancashire.

In 1835 and 1836, when the study of glacial geology was in its infancy, Sir Richard (then Mr.) Griffith called attention to the marl beds in Wexford, "some of the shells appearing to correspond with those of the (English) Crag"—probably referring to a *Purpura* and *Neptunea contraria.* The gravel or marl he thought might possibly be of Norfolk Crag age, the shelly raised beaches of Ireland elsewhere being in his opinion distinctly newer.

In 1838 Edward Forbes figured a shell in the Malacologia Monensis found by him in the Isle of Man on the sea-shore, which his friend Hugh Strickland afterwards described as *Fusus Forbesii.* Forbes seems to have collected other shells in the Manx drifts, as in his well-known memoir of 1846 on the Fauna and Flora of the British Isles he mentions thirteen, including *Nassa pliocena*, *N. monensis*, and *Fusus Fabricii.*

In the same memoir he dealt also with the fossils found by Captain James in the neighbourhood of Wexford, of which he names about seventy species, including a number of extinct Pliocene or southern forms, as well as others of a distinctly northern facies, the whole suggesting to him "the probability of a communication southwards of the glacial sea, and a sea inhabited by a fauna more southern in character than that now existing" in the district. He says also on p. 44, "It can scarcely be doubted that during the newer Pliocene epoch there was a communication open between the Mediterranean and Northern Seas." He again alluded to the subject in 1859 in the *Natural History of the European Seas*, where on p. 114 he says, "I still stand by these opinions."

The next notice of the Wexford shells was in the lists published by myself in the Reports of the British Association for 1888 and 1890.[1] Somewhat later the Manxland fauna was dealt with by Professor Kendall (*Glacial Geology of the Isle of Man*, 1894) and by Mr. Lamplugh in the Survey memoir of the island (1903), their lists including all the species that had been recognized from that region.

More lately Mr. F. W. Harmer, examining the Rev. S. N. Harrison's collections of Manxland fossils, as well as that at the Jermyn Street Museum, discovered some other species of the older type, which he described, and figured in his recent work on the *Pliocene Mollusca of Great Britain*,[2] giving a list of twenty-two shells which he considers may represent a pre-Pleistocene fauna.

From personal acquaintance with both localities, and a fairly exhaustive one of the western faunas generally, I am led to the opinion that the Wexford and Manx beds form portions of a deposit *older* than that assigned to the great Irish Sea glacier, a view that has not been generally entertained. The only mainland molluscan fauna that can be tentatively collated with the Wexford–Manx Series is the one originally described by the late Mr. R. S. Darbishire[3]

[1] pp. 43, 410.
[2] Palæont. Soc., 1914, p. 123.
[3] Quart. Journ. Geol. Soc., vol. xxx, p. 38, 1874.

in a paper on some fossiliferous gravels at Worden Hall, Leyland, 5 miles south of Preston, Lancashire, in which he says "the assemblage of species as a whole most nearly represents that of the Wexford gravels, of which it may not be too wild to consider this deposit a Lancashire representation". Five or six years afterwards when Miss H. Ffarington, the original collector of the shells referred to, had largely augmented Mr. Darbishire's list of forty-three species, I had the pleasure of examining her collection, and was able to identify ninety species in it, which were afterwards recorded in a privately printed catalogue. Of these *Trophon Fabricii*, *Neptunea contraria*, and *Volumitra groenlandica* seem to connect the Worden deposit with that of Wexford and Manxland; but otherwise the fauna identifies itself more closely with that of the drifts of Ballybrack Bay, co. Dublin.

Below I have given three lists of the Mollusca found in Wexford and North Manxland that appear distinctive, the first containing the names of forty-one species, presumably Pliocene, not known to be living, the second of six species confined to seas south of Great Britain, and the third of thirty-three exclusively northern types. Of the total number of eighty species recorded, it may be said at once that only twelve (indicated in the lists by * and †) occur in any fossiliferous Pleistocene deposit elsewhere in Ireland, Wales, Lancashire, or North-West England, and these are all well-known living shells, the forms being absolutely strangers to any of these localities. The difference in the two faunal groups might be still further enlarged if species still living in adjacent waters were considered. Of the 104 shells collected in the Wexford–Manxland drifts only seventy-four species have been recorded from all the other Pleistocene horizons, the latter also yielding a number of species not yet known to the Wexford–Manx fauna.

Although the fossils of Wexford and the Isle of Man are not quite identical in species, it will be seen from the lists that they are of the same general character, and this resemblance is, I think, of more importance than their differences in details, differences that may be expected to disappear as the faunas of the two areas become better known. Crag workers know by experience that two sections of similar age in the same neighbourhood often vary considerably in their contents. On the other hand, the fossils of the high-level drifts and the shelly clays offer a striking contrast. Of the 140 or so species recorded in them not more than 24 or 25 are exotic, and these are chiefly northern. All the rest still live in the adjacent seas, and vary in their condition, preservation, and distribution.

The following analysis of the foregoing lists may be of interest as showing the distribution and range of the Wexford–Manx fauna in the separate areas.

	Wexford.	Manxland.
Pliocene or not known living .	11	37
Recent, but not British, Southern .	5	1
,, ,, Northern .	18	28
Still living in British waters .	72	80
Total .	106	146 species in each area.

List of the more characteristic Species of Mollusca obtained from Wexford and the Isle of Man, showing their general distribution and their agreement or otherwise with each other.

Pliocene Species.	Wexford.	Isle of Man.	Coralline Crag.	Red Crag.	St. Erth.	Other localities.
Cerithium tricinctum, Brocchi		x	x	x	x	Biot, Italy.
Columbella sulculata, S. V. Wood	x			x		
Conovulus pyramidalis, J. Sowerby	x		?	x	x	Slains.
Desmoulea conglobata, Brocchi		x	x	x		Italy.
Eulimella (?) *obtusa*, sp. nov.		x				
Euthria, sp. nov.		x				
Fusus longiroster, Brocchi		x				Biot, Italy.
F. Rigaccii, Cerulli-Ireki		x				
Mitrella sp., Kendall		x				
Murex rudis, Borson		x			x	Italy.
M. Harrisoni, sp. nov.		x				
M. (*Ocinebra*) *tortuosus*, J. Sowerby,						
var. *minor*, F. W. Harmer		x	x	x		
var. *mona*, nov.		x				
Nassa consociata, S. V. Wood, var. *brevis*, F. W. Harmer		x		x		
N. elegans, Leathes		x		x		Slains.
N. granulata, J. Sowerby,						
var. *fenestrata*, F. W. Harmer		x		x		
var. *gracilis*, F. W. Harmer		x	x	x		
N. Kermodei, Kendall		x				
N. monensis, Forbes		x		x		
N. reticosa, J. Sowerby,						
var. *costata*, S. V. Wood	x	x	x	x		
var. *lineata*, F. W. Harmer		x		x		
N. Woodwardi, F. W. Harmer	x	x		x		
Neptunea contraria, Linné	x	x		x		Worden, Gloppa.
Raphitoma lævis, sp. nov.	x	x				
Searlesia costifer, S. V. Wood,						
var. *monensis*, F. W. Harmer		x				
var. *β*, J. Sowerby		x		x		
S. Forbesii, Strickland		x		x		
S. Harrisoni, A. Bell		x				
S. Kermodei, sp. nov.		x				
S. Lundgrenii, Mörch		x		x		Iceland.
S. Nordmanni, F. W. Harmer		x				
S. φyeni, F. W. Harmer		x				
Sipho curtus, Jeffreys, var. *exilis*, F. W. Harmer		x		x		
S. hibernicus, sp. nov.	x	x				
S. menapiæ, A. Bell	x	x				
S. tortuosus, Reeve, var. *lirata*, F. W. Harmer		x	x	x		
Trophon Bailyi, A. Bell	x					
T. Harmeri, sp. nov.		x				
T. Lamplughi, F. W. Harmer		x				
Turritella incrassata, J. Sowerby	x	x	x	x		
Acila Cobboldiæ, J. Sowerby	x			x		

Southern Species.	Wexford.	Isle of Man.	Coralline Crag.	Red Crag.	Other localities.
Cypræa pyrum, Gmelin	x				
Fusus rostratus, Deshayes	x				
Nassa semistriata, Brocchi	x				
Leda pusio, Philippi	x				
Pectunculus pilosus, Linné	x		x	x	
Woodia digitaria, Linné		x	x	x	
Northern Species.					
Admete viridula, Fabricius		x		x	
†*Bela exarata*, Möller	x	x		x	
B. harpularia, Couthouy	x	x		x	
B. nobilis, Möller	x	x		x	
**B. pyramidalis*, Ström.	x	x		x	
B. rugulata, Möller		x		x	
B. scalaris, Möller	x			x	
Buccinum meridionale, Verkrüzen (MS.), var. *elongato-undosa*, Sparre Schneider (MS.)	x	x			
**Dentalium abyssorum*, G. O. Sars		x			
Meyeria alba, Jeffreys	x			x	
**Natica affinis*, Gmelin	x	x		x	
†*N. groenlandica*, Beck	x	x		x	
Parasipho Kröyeri, Möller		x		x	
Purpura incrassata, J. Sowerby	x	x		x	
**Scalaria groenlandica*, Chemnitz	x			x	
Sipho latericeus, Möller	x	x		x	
Taranis Mörchii, Malm		x			
**Trophon clathratus*, Linné	x	x		x	
†*T. Gunneri*, Lovén		x			
T. Fabricii, Beck		x			Worden.
T. lamellosus, Gray		x		x	
**Volumitra groenlandica*, Gray	x	x			Worden.
Astarte Banksii, Leach		x		x	
**A. borealis*, Chemnitz	x	x			
A. Richardsoni, Reeve		x			
A. semisulcata, Leach		x			
Mya uddevallensis, Forbes		x			
Nucula proxima, Gould	x				
Nuculana minuta, Möller, var. *tumida*		x			
**N. pernula*, Möller	x	x			
Serripes groenlandicus, Chemnitz		x		x	
**Tellina calcarea*, Chemnitz		x		x	
Yoldia hyperborea, Lovén	x				

* Occurring in the high-level drift of Wales, Cheshire, Staffordshire, and Lancashire; † in the shelly clays of North-East Ireland.

Of the 41 Pliocene species recorded above, 7 occur in both localities, Wexford and Manxland; of the 33 recent northern shells, 13 of them, and 50 of the recent British forms, are present in both.

It has been suggested that the beds in question contain a mixed collection of fossils derived from deposits of different ages, but this explanation seems to me improbable. They all have a similar appearance, and their mineral condition and conservation are the same. Furthermore, as specimens of the older type are found in areas so wide apart as Wexford and the north of the Isle of Man, one may fairly ask why no traces of such shells have been found in undoubted Pleistocene deposits on either side, or in the deep borings at the Point of Ayre in the north of the Isle of Man beyond the edge of the Shellag Sands, where the fauna is certainly of Pleistocene age. Another feature of the Wexford–Manx fossils may be worth notice, that is, the local abundance of certain species, such as *Buccinum*, var., *Purpura incrassata*, or a strong form, now lost, of *P. lapillus* and *Neptunea contraria*, whose "extinction as a race" Forbes referred to the upheaval of the Irish sandy beds. Of the latter species I have had as many as thirty at a time sent me from Blackwater, co. Wexford.

To my mind, we have on this western area several different stages in later geological history, of which this is one of the oldest: the admixture of Mediterranean Pliocene forms with those of Iceland justifying Forbes's suggestion of a former communication. The later deposits being of Pleistocene age are usually believed to have been brought into their present position by the action of the great Irish Sea glacier. However this may be, with many apologies to those who differ from me, I am *not* prepared to admit that the Wexford–Manx beds originated in the same way, differing as they do in their specific contents, method of distribution, and condition.

In conclusion, I desire to offer my best thanks to the Rev. S. N. Harrison and Mr. Kermode, of Ramsey, Isle of Man, and the Rev. Father Codd, of Blackwater, Wexford, for the loan and gift of many specimens; to the officers of H.M. Geological Survey, London, to Professor Cole and Mr. Hallissy, Dublin, and to Dr. Cowper Reed, Sedgwick Museum, Cambridge, for the opportunities of examining the various collections under their charge; and, not least, to my friend Mr. F. W. Harmer, for his kindly help, assistance, and suggestions for this paper.

The physical and local stratigraphical details I hope to be permitted to deal with later on, as seen from my point of view.

VIII.—New Fossiliferous Horizon in the Coniston Grits of Windermere.

By the Rev. Canon Crewdson, M.A.

FOSSIL remains in the Coniston Grit Series in the Lake District are generally so scarce, except in the flaggy beds exposed in the quarry near Latrigg on Applethwaite Common, that considerable interest attaches to the discovery, made in January of the present year, of a bed which is highly fossiliferous, in a quarry recently opened in connexion with the drainage works of Bowness and Windermere. The quarry is close to the shore of the lake, near the south-west corner of the Calgarth estate.

The newly exposed beds occur at an horizon some distance above the Latrigg band, but a good way below the overlying Bannisdale Slates. They appear to correspond in character with the band noted by Professor Hughes as occurring in the grits at Winder and Crook, about three-quarters of a mile north of Sedbergh[1]; but the matrix in which the Windermere fossils are embedded is much finer than the Winder rock, a condition which is frequently observed in comparing the correlatives of the two localities. It is possible that the Calgarth Beds are actually the equivalents of the Winder Grits; but as Professor Hughes states that the latter are within 1,200 feet of the base of the Coniston Grits of the Sedbergh district, and as the basal grits of that district are equivalents of the Upper Coniston Flags (Upper Coldwell Beds of Lakeland), the Calgarth seam may be at a higher horizon than that of Sedbergh. In any case the bands belong to the same general series, for the Winder Grit is in the coarser grits of Sedbergh, which represent the Coniston Grits of Windermere, and not in the lower flaggy grits which are equivalent to the Upper Coldwell Beds.

The fossils have generally weathered in bands which closely resemble those which are so frequently observed in the Kirkby Moor flags, the fossils being very crowded, but all the carbonate of lime of the shells has been removed. Better preserved fossils are sometimes abundant in the unweathered portions, but it is very rarely that the stone breaks so as to give a good exposure.

There is another quarry a few yards from that in which the fossils were found, but I was unable to find in it any trace of organic remains; it is, however, quite possible that some may yet be discovered, as my examination was unavoidably very cursory.

Dr. Marr, to whom I showed the specimens I procured, has very kindly had them named by Miss Elles, Sc.D., according to the appended list. He has sent me the following paragraph from a work on the Geology of the Lake District which he is at present writing: "Prof. Hughes has described under the name of Crook and Winder Grit a coarse band of calcareous grit which is found among the Coniston Grits of the hills near Sedbergh. This grit may be also represented in the Lake District, and should be looked for. A specimen of yellow grit collected by Ruthven, and preserved in the Kendal Museum, is labelled 'Applethwaite'. It contains Monograpti, Crinoids, and Brachiopods, and may be a representative of the Winder Grit."

I think that the grit which I have described may be the deposit for which Dr. Marr has requested that search should be made, though, as stated above, it is not necessarily on the horizon of the Winder Grits, nor, so far as has been hitherto ascertained, does it contain any traces of Graptolites, like the specimen in the Kendal Museum.

I am greatly indebted to Dr. Marr for his help in preparing this paper, and also to Miss Elles for naming the fossils.

[1] See Memoirs of Geological Survey, Explanation of Quarter Sheet 98 N.E., pp. 14–6.

Miss Elles, Sc.D., has kindly furnished the following preliminary list of fossils from the deposits:—

Orthoceras sp.
Dalmanella (*Orthis*) *elegantula* (Dalm.).
Skenidium Lewisii (Dav.).
Cœlospira (*Atrypa*) *hemispherica* (Sad.).
Camarotœchia (*Rhynchonella*) *nucula* (Sad.).
Dayia (*Rhynchonella*) cf. *navicula* (Sad.).
Strophomena antiquata (Sad.).
Zygospira sp.
Murchisonia cf. *torquata* (McCoy).
Holopella cf. *tenuicincta* (McCoy).
Cyclonema sp.
Cornulites.
Monticulipora fibrosa (McCoy).
Crinoids, Bryozoans, and Corals, and perhaps Trilobites, but nothing identifiable.

REVIEWS.

I.—Memoirs of the Geological Survey.

The Geology of the South Wales Coalfield. Part XI: The Country around Haverfordwest, being an account of the region comprised in Sheet 228 of the Map. By Aubrey Strahan, Sc.D., F.R.S., F.G.S., T. C. Cantrill, B.Sc., F.G.S., E. E. L. Dixon, B.Sc., F.G.S., H. H. Thomas, M.A., B.Sc., F.G.S., and O. T. Jones, D.Sc., F.G.S. pp. i–vii, 1–262. 1914. Price 3*s*. 6*d*.

THE memoir before us deserves a somewhat extended notice, for much of its contents is of more than local interest. Were we to start our classification of the Lower Palæozoic rocks afresh, we should probably adopt this area as the type-area of the rocks of Ordovician age, and the lower division of the Silurian strata is also remarkably well represented. It is safe to say that students of the Ordovician and Lower Silurian strata will in future turn again and again to the pages of the memoir. The map of which the memoir is descriptive has not yet been published.

The district includes rocks of Pre-Cambrian, Cambrian, Ordovician, Silurian, Old Red Sandstone, Carboniferous, and Eocene (?) ages, and also Glacial and Post-Glacial accumulations.

The oldest rocks occur in two masses south of the coal-field, the southerly being termed the Benton Series (which also appears in a smaller patch further south) and the northerly the Johnston Series. The rocks of the former consist of acid lava-flows with tuffs and agglomerates which are probably of more basic character. The Johnston Series is one of plutonic rocks consisting (in the order of their intrusion) of quartz-diorites, quartz-albite rocks, and quartz-dolerites. The two series adjoin for about a mile, but the nature of the junction is unknown. The Rosemarket Rocks (of Valentian age) probably rest unconformably on the Benton Series, and the Johnston Rocks are also presumably older than the Rosemarket group. There are reasons for supposing that these Johnston Rocks are Pre-Cambrian, and it is likely that the Benton Series also should be referred to that age. Cambrian rocks of Lower Lingula Flag age are exposed on the east of the Western Cleddau at Spittal Cross and Trefgarn Bridge, and on the west of that river near Leweston and Wolfsdale.

The development of the Ordovician strata, notwithstanding certain breaks, is very complete, and the small thickness of intercalated volcanic rock renders them easy of study; moreover, they show alternations of the 'shelly' and 'graptolitic' types of these strata.

The Arenig beds are representative of the lower (*Didymograptus extensus*) and upper (*D. hirundo*) zones so widely distributed elsewhere. The beds have not been separately mapped on account of the thinness of the *D. hirundo* zone, but are distinguishable on the ground. An ash occurs in the *extensus* beds of the Henllan Amgoed district, and a more important volcanic series consisting of lavas and tuffs developed near Trefgarn Bridge is probably on the same general horizon. The succeeding beds with *Didymograptus bifidus* are separated from the Arenig Series and placed in what Dr. Hicks termed the Llanvirn Series, characterized especially by 'tuning-fork graptolites'. In the Haverfordwest district the Lower Llanvirn beds (with *D. bifidus*) are alone represented, the Upper Llanvirn with *D. Murchisoni* being absent. Nevertheless it is interesting to find fossils hitherto referred to the Llandeilo, as *Ogygia Buchi* and *Calymene cambrensis*, in these beds. Indeed, the detailed survey of this area has shown the longer range of many other fossils of various strata.

The Llandeilo Series is divided into two groups of strata, the Llandeilo Limestone and Flags below and the lower part of the *Dicranograptus* beds above. These are dealt with in separate chapters. The lower group rests on the *bifidus* beds and decreases in thickness from south to north, with a corresponding diminution of the fauna. This suggests the existence of a land area to the south, with an east and west trend.

The *Dicranograptus* Shales are partly Llandeilo and partly Bala. They are subdivided into the basal Hendre Shales, the Mydrim Limestone, and the Mydrim Shales at the top.

The Hendre Shales are thinner than in the district to the east, partly owing to their lower part having passed laterally into the Llandeilo Limestone and Flags. They have a definite Llandeilo fauna. The surveyors draw the line between Llandeilo and Bala at the base of the Mydrim Limestone. This limestone has the graptolite fauna of the *Nemagraptus gracilis* beds, which Lapworth, when describing his classic sections at Moffat, correlated with part of the Llandeilo Series. One is disposed, therefore, to doubt the desirability of drawing the line where the Surveyors have placed it, and to avoid confusion would prefer to have it placed at a higher horizon.

The Mydrim Shales, as a result of Miss Elles' work in another Welsh area, have been divided into four graptolitic zones.

The Robeston Wathen Limestone with numerous corals shows evidence of overstepping the underlying strata. It has elsewhere been regarded as the upper division of the Caradocian division of the Bala Beds, the succeeding strata having been referred to the Ashgillian division. With this the Surveyors appear to agree.

The Shoalshook Limestone has long been known for the richness of its fauna. It forms the base of the Ashgillian representatives, and these Ashgillian strata are shown to rest unconformably upon the lower beds. This limestone from the presence of *Diplograptus*

(*Orthograptus*) *truncatus* (?) is assigned to either the upper part of the zone of *Dicranograptus Clingani* or the lower part of that of *Pleurograptus linearis* in the Scottish Southern Uplands. As *D.* (*O.*) *truncatus* var. *abbreviatus* is found in what appear to be corresponding beds in the neighbourhood of Sedbergh, along with *Dicellograptus anceps*, it may be suggested that the Shoalshook Limestone may possibly be on the horizon of the last-named zone.

The highest Ordovician strata, the Redhill–Slade Beds, exhibit a northern and a southern type. Fossils are rare in the northern type.

The Silurian beds belong to the Valentian (Llandovery–Tarannon Series). They seem in places to grade down into the highest Ordovician strata, though elsewhere a conglomerate occurs at the base. They are divided into three stages: these are, in ascending order, the Haverford, Millin, and Rosemarket stages. The beds of the last-named occur in a different tract to that showing the two former stages, being developed on the south side of the coal-field. "It may be observed that on the whole the Haverford stage corresponds to the so-called Lower Llandovery, while the Rosemarket stage may be matched with part of the Upper Llandovery, but there is difficulty in correlating the Millin stage with either of these subdivisions, and it probably forms a group which is only partly represented, if at all, in the district of Llandovery." The rich fossil lists from the Valentian beds of this district will be extremely valuable to future workers among the Llandovery rocks.

Passing to the Upper Palæozoic rocks, we find the Old Red Sandstone occurring both to the north and the south of the coal-field. The rocks differ widely in their characters. The beds are divided into a lower group consisting of red marls with sandstones, conglomerates, and breccias, and an upper group (the Skrinkle Sandstones). The Lower Old Red Sandstone is everywhere unconformable to the older rocks, while the Upper Old Red Sandstone is followed conformably by the Carboniferous strata. Both groups are absent near Haverfordwest, owing to westerly overstep of the Carboniferous rocks. The beds of the lower division have yielded *Pteraspis* and some plants, including *Psilophyton* (?).

The Carboniferous Limestone is also developed to the north and south of the coal-field. A closer comparison can be made between the northern beds and those further east, and also between the southern beds and their easterly equivalents, than between the northern and southern beds of the area under consideration. It is suggested that the area of deposition of these rocks in South Wales shallowed northward towards a coast with a general east and west trend.

The series corresponds in the main with the Avonian Series of Dr. Vaughan. The following zones are recognized in descending order:—

Dibunophyllum zone (lower sub-zone D 1 alone known).
Seminula zone.
Syringothyris zone.
Zaphrentis zone.
Cleistopora zone.

Evidence is given in favour of a division into Lower and Upper Avonian between the two subzones of the *Syringothyris* zone (where an unconformity occurs), and not at the top of that zone. In connexion with this, interesting sections showing contemporaneous piping of mudstones into oolitic limestones of the lower part of the *Syringothyris* zone are described, and the phenomena are illustrated in two plates.

The Carboniferous Limestone in this area rests conformably upon the Old Red Sandstone, but is succeeded unconformably by the Millstone Grit: in neither case do we get information about faunas of passage beds between the Carboniferous Limestone and the older and newer strata.

The Millstone Grit is divided into three divisions, which do not show any features of exceptional interest.

The Coal-measures are naturally described in great detail. Only the eastern portion of the Pembrokeshire Coal-field is represented in the district of which the memoir under consideration is descriptive.

The coal-field here is broadly a syncline, but while the various subdivisions lie in normal superposition on the northern side of the trough, the central and southern portions are complicated by inverted folds and an almost infinite number of large and small overthrust faults. The basin here has been involved in two great belts of disturbance. On the south it is touched by the northern margin of the Armorican belt, with overthrusting and overfolding from the south; on the north it is affected by disturbances which also affect the Old Red Sandstone and Ordovician strata, and show evidence of overfolding and overthrusting from the north; in the centre there is comparatively little signs of disturbance.

The coals of this area are all anthracitic. The lower series, and probably only the lower half of that series, of the Coal-measures of Carmarthen and Glamorgan is alone represented in East Pembroke, and it is impossible to correlate with certainty the individual seams of this latter area with those of the former. Three seams have yielded the bulk of the coal, namely, the Rock, Timber, and Lower Level and Kilgelty veins.

There are no Triassic rocks in the district, but their former presence is indicated by reddening of the Carboniferous rocks.

Certain vein-quartz pebbles in a subsoil near Coedcanlas are noticed and referred to a possible Eocene date.

A very interesting chapter on Tectonics follows the description of the strata. The nature of the chief movements and their effects has already been noticed.

A raised beach overlain in one place by glacial drift corresponds both in position and age with one which occurs at intervals all around the Bristol Channel.

The glacial drifts are described, and a map on p. 218 indicates the distribution of the boulders and their directions of transport. There are also notices of river-terraces and of a submerged forest.

A chapter is devoted to economics, and notices lime and limestone, building stone, bricks, roadstone, timber, and water-supply. The character of the coal is dealt with in another memoir.

Four appendices treat of the fossils and of photographs of geological subjects belonging to the Geological Survey.

The method of indicating fossil localities in Appendix I should be specially noted. By means of this, and on consulting the 6 in. maps preserved in the Survey Office, the exact locality of any specimen may be ascertained. We may hope that this admirable example may frequently be followed by others, for nothing is more annoying than to find a vague locality given for an important fossil.

In congratulating all the authors of the memoir upon its matter, it may be remarked that while full credit is given to previous workers in the district for what they have done, the mistakes which they have made are touched upon so lightly that they can usually be detected only by consulting the original papers in which they appear.

J. E. M.

II.—The Water of Volcanoes.

In the Geological Magazine for 1911 the present writer reviewed a very striking book entitled *Recherches sur l'exhalaison volcanique,* written by Albert Brun of Geneva.[1] Brun's claim to have banished water-vapour from among true volcanic emanations has now been critically tested by Day & Shepherd[2] in its application to Kilauea, and has been satisfactorily disposed of. Brun has not laboured in vain, however, even apart from the many interesting side-issues which he has raised. One feels, on reading the account given by Day & Shepherd of their experiences, that the long-accepted belief in the importance of volcanic waters was in urgent need of direct confirmation. No experimenters could have entered upon the task with a greater prestige, and the result obtained will doubtless carry conviction. Those who imagine that the water of volcanic activity is a self-evident fact will be surprised to read that, although Day and Shepherd undertook their study of Kilauea on May 1, 1912, and waited till May 28 before an opportunity of collecting the gases at last arose, they were even then caught quite unprepared for the water which collected in their tubes; so much so that they had actually no apparatus ready at hand to estimate the proportion of the water to the other volatile matter discharged by the lava! Moreover, it will be remembered that Lowthian Green, who as a resident in the Hawaiian Isles enjoyed exceptional opportunities of observation, never subscribed to the prevalent aqueous theory of volcanoes.

Green's difficulties, it may be recalled, originated in his regarding the intensity of the great white cloud of the volcano as a measure of the vapours discharged. Where Green saw no cloud, he thought that but very little vapour was liberated. But Day & Shepherd prove that the cloud consists essentially of finely divided sulphur. Where the vapours are released into the atmosphere direct from the molten lava, they burn, and their products are invisible. It is only, where cooled down by passage through fissures of the shattered floor around the lava-lake, that the vapours yield the characteristic white cloud.

Brun's observation that the cloud consists of solid particles thus remains unchallenged. Brun noticed that the cloud when present

[1] See Geol. Mag., 1911, pp. 268, 311.

[2] A. L. Day & E. S. Shepherd, "Water and Volcanic Activity": Bull. Geol. Soc. Am., vol. xxiv, p. 573, 1913.

does not evaporate, that it gives no rainbows, and that it is immediately visible without an initial transparent zone, and these are just the results to be expected if the cloud contains much sulphur. But these phenomena, though they confirm Brun's statement that the great white cloud consists of solid particles, do not prove the absence of water; in passing it may also be mentioned that the impression one gathers from Brun's account that the solid particles of the cloud are crystallized salts must be revised.

Now it will be remembered that Brun made a series of experiments on the hygrometric state of the Kilauea cloud, and found it uniformly lower than that of the atmosphere outside. This observation serves as a corner-stone in Brun's statement of his case, but is set aside by Day & Shepherd as quite untrustworthy. The cloud, it seems, was sampled more than 250 feet from the point of emergence of the gases, while the presence of oxides of sulphur must in any case have lowered the dew-point very considerably.

Thus it appears that Day & Shepherd have kept in view the work of their predecessors, and thereby materially strengthened the presentation of their own results.

The following are the circumstances under which they successfully collected the volcanic gases. A column of lava had worked its way through the shattered floor adjacent to the great active basin, and formed a lava-fountain several feet in diameter. The lava quickly built up a closed spatter-dome, and at night gases could be seen burning as they escaped through narrow cracks. It was clear that an excess of pressure reigned within the dome, and that there was no fear of admixture with air.

The gases were drawn by a pump from the interior of the spatter-dome. Twelve inches of iron pipe were inserted into the dome, and behind this were 20 feet of glass tubing. The gases entered at about 1,000° C. Water began condensing in the pipe-line with the first stroke of the pump. This prevented quantitative determinations of proportions, for before sealing the tubes the pumping had to be continued fifteen minutes to ensure the complete displacement of the air present, and all this time water was collecting. In the end about 300 c.c. of water accumulated in the tubes.

The gases found were mainly SO_2, CO_2, and N_2, with less abundant H_2 and CO. Hydrocarbons were absent, while chlorine, free or combined, played a very subordinate role.

The water is regarded as proper to the volcanic emanation on the following grounds:—

1. CO_2 and H_2 cannot coexist at 1,000° C. without the production of water.

2. The FeO, resulting from the interactions of the short iron tube and the SO_2, is not likely to have been more efficacious in oxidizing the hydrogen of the emanation than the 10 per cent of ferrous oxide present in the magma.

3. If the water collected represents hydrogen in the original emanation, then hydrogen must constitute at least 40 per cent of the emanation. This would entail violent explosions whenever the emanation is liberated into air, but as a matter of observation

bubbles of gas, even 30 feet in diameter, burst without giving any explosion whatever.

The nitrogen of the emanation was handed over to Professor R. W. Wood for examination for rare gases. The result was negative; and the absence of argon is taken as a further proof that the volcanic gases had been successfully collected free from atmospheric contamination. It is further held by the authors as an indication that the magmatic nitrogen was not originally atmospheric in origin. Here it seems to the writer that there is room for doubt. Is it not possible that nitrogen possesses an advantage over argon either in the process of diffusion through solid rock-masses or perhaps in that of solution by silicate magmas? However, Day & Shepherd are satisfied that magmatic nitrogen is an essentially original constituent, and conclude that magmatic water is in all probability in a like category; for water above its critical temperature loses the advantage due to surface tension, which is the basis of Daubrée's famous experiment.

E. B. Bailey.

III.—The Deposits of the Useful Minerals and Rocks, their Origin, Form, and Content. By Professor Dr. F. Beyschlag, Professor J. H. L. Vogt, and Professor Dr. P. Krusch. Translated by S. J. Truscott. In three volumes. Vol. I: pp. xxviii+514, with 291 illustrations. London: Macmillan & Co., Ltd., 1914.

The authors of the original German edition, all three of whom are among the foremost living authorities on the subject, have planned a most comprehensive and ambitious treatise on ore-deposits. When they complete their project they will have included within their purview not only ore-deposits as ordinarily understood, that is to say those metalliferous in character, but also deposits of coal, salt, and mineral oil, and will have therefore covered the whole range of minerals and rocks which have been mined. The first volume appeared in 1910; the second volume was published in two parts, the first in 1912 and the second in 1913. This treatise differs from the earlier standard works on the subject (viz., Dr. Richard Beck's *Lehre von den Erzlagerstätten*, of which a third edition appeared in 1910, and *Die Erzlagerstätten*, began by Professor Stelzner and completed by Dr. Alfred Bergeat, which was published in parts, i and ii in 1904 and iii in 1906) in that the discussion is based upon broad geological principles; while in the two works mentioned the tendency has been more to bring together copious and detailed descriptions of the important mining regions.

The volume we have before us is the English translation of the first volume of the German edition. The task of preparing the translation has been undertaken by Mr. S. J. Truscott of the Royal School of Mines, London, and has been admirably performed. In his preface he modestly says, "I have endeavoured faithfully to bring out both the fact and the spirit of the authors' work, this being of such high standard that the reception of a translation must depend largely upon the degree of closeness with which the original is approached." There can be no question of his success, but, we may add, he has not adhered so slavishly to the original as to mar the ease of diction:

there is nothing, beyond the fact that many of the illustrations are drawn from the collection of the Geologische Landesanstalt in Berlin, to suggest the original foreign source. He has been at great pains to study the precise meaning of the technical words, and in his preface gives an interesting essay on the subject. The German word *Gang*, for instance, may be translated as either 'lode' or 'vein'; the latter has a similar sense to the former, but is of a less important character, though, it is pointed out, the meaning has been somewhat confused by the vagaries of American Law phraseology.

The first volume includes five principal parts: viz. on ore-deposits in general, magmatic segregation, contact-deposits, tin-lodes, and quicksilver lodes. Neither the parts nor the chapters comprising them are numbered. The first part occupies nearly half the volume, and includes such important chapters as those on classification, form and graphic representation of ore-deposits, mineral formation, the relative distribution of the elements and their natural associations with especial reference to the metals, the origin of ore-deposits, the absolute and the relative amounts of the metals in useful ore-deposits, primary and secondary depth-zones, indications of ore-deposits at the surface, and the scientific classification of ore-deposits. A conspicuous and important feature of the book is the excellent bibliography that heads each section, the student being thereby placed in touch with all the principal books and memoirs written on the subject in question.

Probably the reader already acquainted with the subject will first look to see what classification has been adopted by the authors. Many systems have from time to time been suggested, all of which are referable to three different types, viz. according as they are based upon the shape, the content, or the genesis of the deposit. The first has much to commend it from the practical mining, and the second from the commercial point of view, but neither can be defended on scientific grounds, and the third alone remains. Like most recent writers, the authors adopt a classification based upon Stelzner's and divide deposits into two main groups—the syngenetic, ores formed contemporaneously with the rocks surrounding them, and the epigenetic, ores formed subsequently. In a later chapter they put forward a complete scientific classification consisting of four main groups: I, magmatic segregations; II, contact deposits; III, cavity fillings and metasomatic deposits; IV, ore beds. In a second edition they will no doubt include some reference to the highly interesting and cogent paper which Mr. T. Crook, of the Imperial Institute, read before the Mineralogical Society, and published in the *Mineralogical Magazine* last July. In it he considers the classification of rocks, regarding ore-deposits rightly as only a special case of the problem, and points out grave objections to all the existing schemes of classification. For instance, Stelzner's main groups often unite the different and separate the similar; to quote Mr. Crook, "Thus ore deposits resulting from igneous activity may be either 'syngenetic' or 'epigenetic'; the 'syngenetic' group includes both igneous segregations and sedimentary deposits; and vein deposits are 'epigenetic' whatever may have been the origin of the solutions from which they have been deposited." He himself suggests a grouping based upon a genetic geological basis, as follows: I. Endogenetic deposits: (1) igneous segregations, (2) igneous exudations, (3) deposits in thermo-dynamically altered rocks (unfused and unimpregnated). II. Exogenetic deposits: (1) weathering residues, (2) detrital deposits, (3) solution deposits, (4) subaerial plant accumulations and their products.

Many famous mineral localities are incidentally described in this volume: among them may be mentioned the gold-telluride mines in Western Australia and Colorado, the quicksilver mines at Almaden, the Broken Hill silver-lead mines, the Burra Burra copper mines, the famous Swedish iron deposits, the pyrites deposits at Rio Tinto, the Saxon–Bohemian Erzgebirge, the Straits Settlements tin deposits, and the Cornish mines.

The volume is admirably illustrated and provided with excellent subject and geographical indices, and is altogether one that should find a welcome home on the shelves of all who are interested in either rocks in general or ore-deposits in particular.

IV.—Brief Notices.

1. The Production of Mineral Waters in 1913; with a Discussion of their Radio-activity. By R. B. Dole. Mineral Resources of the United States, calendar year 1913. Part II. pp. 393–440. 1914.

THIS report contains statistics of the natural mineral waters of the United States, arranged according to States. It includes two features of interest: a bibliography of mineral water analyses, and a short account of the radio-activity of mineral waters. Many mineral waters do not differ in any obvious way from ordinary town supplies in their composition. Yet such waters have a distinct therapeutic value, and in recent years the previously obscure curative agent has been identified with radio-active ingredients which the medicinal waters have been found to contain. A table showing the radio-activity of about fifty well-known waters is given, but unfortunately the radio-activity is expressed according to five different units, and direct comparison is thus impeded. A bibliography is provided of literature bearing on radio-activity and radio-therapy, and is a useful compilation; but one notices the rather serious omission of Sir E. Rutherford's *Radio-active Substances*, 1913, which should have taken the place of his 1906 book.

2. Portuguese East Africa.—Messrs. E. O. Thiele and R. C. Wilson publish in the *Geographical Journal* for January, 1915, a tectonic and physiographic account of the area between the Zambesi and Sabi Rivers. But in the discussion, which followed, are some remarks by Mr. R. B. Newton on important fossils collected, and these remarks are liable to be overlooked. The collection is now in the British Museum, and belong to Upper Cretaceous, Lower Eocene, and Miocene times. The latter is recognized for the first time from the presence of the foraminiferal genus *Amphistegina*; whereas the Eocene was identified from *Nummulites* as far back as 1896 (Geol. Mag., 1896, 487) from material collected by David Draper about 100 miles south of the area whence Mr. Thiele obtained his specimens.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

Annual General Meeting.

1. *February* 19, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The Reports of the Council and of the Library Committee were read.

The Awards of the various Medals and Proceeds of Donation Funds in the gift of the Council were enumerated.

The Reports having been received, the President handed the Prestwich Medal, awarded to Dr. Émile Cartailhac, to Baron Prosper de Barante, Secretary of the French Embassy, for transmission to the recipient, addressing him as follows:—

Baron de Barante,—The Council of the Geological Society has awarded the Prestwich Medal to Dr. Émile Cartailhac, the Nestor of French archæologists and the acknowledged leader of that brilliant band of French investigators who have shed so much unexpected light on the life of man in the Pleistocene Epoch.

Dr. Cartailhac's long-continued labours, extending over half a century, have been crowned by the two noble volumes which adorn the series published by the munificence of the Prince of Monaco. The treatise on the Archæology of the Grottes de Grimaldi is a most valuable contribution to our knowledge of Aurignacian culture, and shows in the clearest manner the cult of the dead which prevailed among the later Palæolithic peoples. The great work on the Spanish Cave of Altamira is a masterpiece of scientific investigation, to which all must turn who would appreciate those remarkable achievements in art that are the glory of the later Palæolithic age.

To his scientific powers and attainments, originality and lucidity, Dr. Cartailhac adds a greatness of mind ready to suffer all things in the cause of truth, and a personal sympathy with his younger colleagues which is the offspring of a natural kindness of heart. The Geological Society has long admired both the man and his work, and will be glad if you will transmit this medal to him as a small mark of its esteem.

Baron de Barante replied in the following words:—

Mr. President,—M. Cambon would have had great pleasure in acknowledging personally the honour bestowed by the Geological Society on Dr. Cartailhac. He has asked me to tell you how sorry he is to have been unable to be amongst you on the present occasion.

The Prestwich Medal is a token of esteem which I am glad to accept on behalf of Dr. Cartailhac, who will value very highly, not only your gift, but also the kind way in which the Geological Society appreciates his labours.

May I add that your words have for us another and a wider meaning? They show once more how tight have grown the bonds between our two nations through the long-standing brotherhood of England and France in the field of scientific knowledge. We have fought side by side for years in the cause of truth and enlightenment, just as we are now together on the battlefield up in arms for the rights of nations, for justice and for liberty.

The President then handed the Wollaston Medal, awarded to Professor T. W. Edgeworth David, C.M.G., to the Right Hon. Sir George H. Reid, P.C., G.C.M.G., High Commissioner for the Commonwealth of Australia, for transmission to the recipient, and addressed him as follows:—

Sir George Reid,—The Council of the Geological Society has this year awarded the Wollaston Medal, its highest distinction, to Professor Edgeworth

David, in recognition of the value of his contributions to our knowledge of the geology of Australasia and the Antarctic regions. Since his appointment to the Geological Survey of New South Wales in 1882, and his subsequent call to the Chair of Geology in the University of Sydney in 1891, Professor David has taken a foremost part in the promotion of geological science in the Australian Commonwealth. His researches on glacial conditions in the Permo-Carboniferous Period, and on the chief tectonic lines of the Australian Continent, have touched problems of the deepest philosophical interest; while his exhaustive works on some of the Australian coal-fields have shown that he is not unmindful of the economic needs of a newly settled country. The energy and skill with which he brought the boring in the coral-atoll of Funafuti to a successful termination will always be remembered with gratitude and admiration by geologists; while his bold venture to take a personal share in the hardships and dangers of exploration on the Antarctic Continent enabled ripe experience to bear on the interpretation of geological phenomena which might have been deemed accessible only to those in the first vigour of youth. We still await the detailed report on Professor David's work during the Shackleton Antarctic Expedition, but his preliminary communications have already allowed us to judge of its real importance.

Professor David has already received many marks of appreciation in Australia, where his kindly nature has endeared him both to colleagues and to students. He is a past president of the Royal Society of New South Wales, and of the Australasian Association for the Advancement of Science; and he was Chairman of the New South Wales Committee which made arrangements for the recent visit of the British Association. The Council of the Geological Society will now be glad if you will convey to him the Wollaston Medal as a renewed token of its esteem and appreciation, with an expression of the cordial wishes of the Society for his continued health and activity.

Sir George Reid, in reply, expressed the pleasure which it afforded him to represent on that occasion an old and valued friend. He dwelt on the great scientific work which Professor David had accomplished in and for Australia, and mentioned that to his expert knowledge Ministers had invariably had recourse when they needed advice on matters connected with science. Not only was Professor David revered in Australia for his scientific attainments, but the charm of his personality and the kindliness of his nature endeared him to all those who knew him.

In presenting the Murchison Medal to Professor William Whitehead Watts, F.R.S., the President addressed him in the following words:—

Professor Watts,—The Council congratulates itself that, owing to the circumstance of your now resting from the responsibilities of office for the first time during some sixteen years, the opportunity is afforded to it of expressing its deep sense of the many obligations which geological science owes to you and to your researches. It is therefore conscious of more than ordinary appropriateness in awarding to you the Murchison Medal, which recalls the memory of the pioneer who made famous the rocks of your native county, Shropshire, and laid the foundations on which you have so admirably based a superstructure. Your researches have extended from Shropshire to the English Midlands, Wales, Scotland, and Ireland, and among your writings known and prized by the rising generation of British geologists, I need only mention your brilliant papers on Charnwood Forest, the igneous rocks of the Midlands, and the Collection of Rocks and Fossils belonging to the Geological Survey of Ireland. Your energies and interests in all branches of geology have passed far beyond the range of an ordinary investigator; and as a teacher of geology you have infected with your enthusiasm numberless students, who have been charmed by the method and clearness of your presentation of the subject, both in the lecture-room and in the field.

In offering you this mark of its appreciation, the Council desires to express the hope that you may long be spared to continue your invaluable service to the progress of our science.

Professor Watts, in reply, said:—

Mr. President,—It gives me much pleasure personally to thank the Council for their award of the Murchison Medal, and yourself, Sir, for the kind and encouraging words in which you have made the presentation. The flattering reference that you have made to my work, while showing how deeply I am indebted to my Cambridge teachers Professor Hughes and Professor Bonney, makes only too clear to me how far performance halts behind ideals.

My long service as Secretary of the Society, my former membership of the Geological Survey, and my share in Professor Lapworth's work in the county where the founder made his classic discoveries, unite in making me proud to possess the Murchison Medal. But there is still another reason why the award is doubly gratifying to me at the present time.

After dwelling in the wilderness for many years, the great institution founded by De la Beche and presided over by Murchison (who allowed it to share the die of his Medal) enters this year into full possession of the beautiful home which has been erected for it at uncounted cost by the Governing Body of the Imperial College. That this learned and representative Society should mark the reincarnation of the Royal School of Mines by sending to it such an appropriate recognition, cannot but be a source of deep gratification to Professor Judd, who designed the practical geological teaching there, to my Staff, who have striven worthily to carry on and extend his methods, to my colleagues in the arts and sciences of Mining, Metallurgy, and Oil-getting, and to the authorities of the Imperial College, who have spared neither thought nor resources in giving to De la Beche's conception a form worthy of it, have placed research in the forefront of the functions of the College, and have permitted the Geological Museum therein to bear the honoured name of Murchison.

The President, in presenting the Lyell Medal to Professor Edmund Johnston Garwood, F.R.S., addressed him as follows:—

Professor GARWOOD,—The Lyell Medal is awarded to you by the Council as a token of its appreciation of your many and notable contributions to geological science. In Glaciology your investigations in the English Lake District, Spitsbergen, the Alps, and the Himalayas, are of fundamental importance; and, as an example of the care with which your work is presented for publication, I need only mention your beautifully illustrated paper on the Tarns of the Canton Ticino in our Quarterly Journal for 1906. In Stratigraphy your long and patient study of the Lower Carboniferous rocks in the North-West of England has resulted in the recognition of a zonal sequence which must be taken as a standard for comparison in all future work on the corresponding formations of the British Isles. In Palæontology you have recently drawn special attention to the importance of Calcareous Algæ as rock-builders, and have already made much progress in the detailed study of their structure.

The Society has followed your researches with sympathetic interest for many years, and, as a former colleague in the Secretaryship, it gives me great pleasure to hand you this medal.

Professor Garwood replied in the following words:—

Mr. President,—I am deeply sensible of the honour which the Council of this Society has conferred on me by the award of the Lyell Medal.

The infinite variety and unfailing interest of the problems that confront the geologist in any original research, in themselves, provide sufficient compensation for the labour expended; but the sympathy and appreciation of fellow-workers is a real and valuable stimulus, and a permanent source of gratification and encouragement.

In glancing at the list of names of former recipients, I notice that the first award of this medal was made to the late Professor John Morris, my predecessor in the Chair of Geology at University College, and it is a great satisfaction to me that the work carried on in the Geological Department at the College should have again received recognition at the hands of this Society. The work entailed in the discharge of official duties connected with the chair leaves but scant leisure for original research; and even the little that I have been able to accomplish towards the furtherance of our science would have been even less but for the ungrudging assistance which I have received in the field from many of my former students.

Passing down the list, my attention is arrested by the name of Dr. Marr—a name which brings vividly before me the debt that I owe to the School of Geology at Cambridge. As in the case of the founder of this medal, the subject of Geology was not included in the course of study which had been mapped out for me on my entrance to the University, and just as Lyell's interest was first aroused by Dr. Buckland's lectures which he attended at Oxford, my enthusiasm was stimulated by the courses delivered by Professor Hughes and Dr. Marr at Cambridge, and I am glad of this opportunity of expressing how much I owe to their help and kindness during my Cambridge career.

To Dr. Marr I am further indebted for his constant encouragement in connexion with my work on the Lower Carboniferous rocks in Westmorland, without which it is doubtful whether the investigation would have ever been brought to a successful conclusion.

To another of my predecessors, Professor Bonney (whose wide sympathies are so well known to the Fellows of this Society), I owe much for his constant kindness and interest in my work, more particularly in the development of certain heresies connected with the interpretation of glacial phenomena.

You have been good enough to allude to my interest in the part played by the Calcareous Algæ as rock-builders. I may therefore perhaps point out that my work in this direction is really a continuation of Lyell's investigations on the same subject, for it was Lyell himself who first called our attention to the importance of plants as agents in limestone formation, in his paper published in the Transactions of this Society in 1829, in which he records the formation of nodules and strata of travertine in a lake near his old home in Forfarshire.

I thank you, Sir, for the kind words with which you have accompanied this presentation; it is an especial pleasure to receive this medal from the hands of one with whom I lately shared the duties of Secretary to this Society.

The President then handed the Bigsby Medal, awarded to Mr. Henry Hubert Hayden, Director of the Geological Survey of India, to Sir Thomas Henry Holland, K.C.I.E., for transmission to the recipient, addressing him as follows:—

Sir Thomas Holland,—The Bigsby Medal has been awarded by the Council to Mr. Henry Hubert Hayden, in recognition of the value of his contributions to our knowledge of the Geology of India. His work touches nearly every phase of geological inquiry, and includes field observations in most provinces of the Indian Empire as well as beyond its frontiers in Tibet and Afghanistan. His exhaustive memoirs on the Central Himalayan region of Spiti, on Kashmir, on Eastern Tibet, and on Afghanistan are mainly concerned with palæontological and stratigraphical problems, but they include also important observations on the physical geography of each region, on the igneous rocks of all, and on their phenomena and metamorphism.

During the past three years, although occupied with administrative duties as Director of the Geological Survey of India, he has found time to make a new excursion beyond the borderland of his subject, in a suggestive discussion of the relations between the geodetic observations and the geological features of the Indo-Gangetic alluvial plain.

A cursory survey of the titles of his papers leaves the impression that they are mainly regional and descriptive in character; a closer study of their contents, however, shows that they add materially, not only to our stock of data, but to the wider philosophical bearings of nearly every branch of geology. They are not the products of the mere student, for the observations which they describe are those that could have been made only by an intrepid explorer, by an expert mountaineer, and by one who possesses, in a pronounced degree, the leading trait of British pioneers in "new lands"—a capable leader of men.

In accordance with the will of its founder, the Bigsby Medal is always given to one who is "probably not too old for further work, and not too young to have done much". In transmitting the award to Mr. Hayden, the Council will therefore be glad if you will also convey its best wishes, with an assurance of its continued interest in the future successful work which it anticipates.

Sir Thomas Holland, in reply, said:—

Mr. President,—My long and intimate personal acquaintance with Mr. Hayden gives me ample justification for assuring the Society that the Council has observed with rigour the terms of the Bigsby Bequest, which expect of the medallist promise of future work in continuation of a meritorious past. No award could give my old colleagues of the Indian Geological Survey greater satisfaction, for they know why I have special reason to regard this honour as abundantly earned.

Both before and during my term of office as Director of the Geological Survey of India, Mr. Hayden was most conspicuously the "handy man" of the Department. He was always ready to face any emergency, regardless of geographical, climatic, or political difficulties; and, as a consequence of the numerous demands made for his official services, his published record, which you, Sir, have now justly reviewed, represents but a fraction of his official and scientific activities.

In thanking the Council in the name of Mr. Hayden and on behalf of the service which he so ably leads, I gladly undertake the duty of forwarding this medal.

In presenting the Balance of the Proceeds of the Wollaston Donation Fund to Mr. Charles Bertie Wedd, B.A., the President addressed him in the following words:—

Mr. WEDD,—The Balance of the Proceeds of the Wollaston Donation Fund is awarded to you as an acknowledgment of the value of your geological work.

At Cambridge you dealt with several problems connected with the local geology, and, later, as a geological surveyor, continued your investigations in the counties of Bedford and Huntingdon. Your work on the Jurassic and Cretaceous rocks has not been confined to England, and our knowledge has been enriched by your careful mapping of these deposits in the Western Isles of Scotland. Latterly, your efforts have been directed chiefly towards the elucidation of Carboniferous stratigraphy. An absorbing interest in field-work, and a patient collection of detail, enabled you to interpret successfully the structure of a most complicated portion of the North Staffordshire Coal-field. Your work on the Carboniferous Limestone and Fluorspar deposits of Derbyshire was a valuable contribution to our science, and your observations on the Glacial History of our Islands, although scattered through a variety of official publications, are of considerable interest. In making this award the Council feels confident that your future work will be as successful and valuable as that which you have already accomplished.

The President then handed the Balance of the Proceeds of the Murchison Geological Fund, awarded to Mr. David Cledlyn Evans, F.G.S., to Mr. T. C. Cantrill, B.Sc., for transmission to the recipient, addressing him as follows:—

Mr. CANTRILL,—The Council has this year awarded to Mr. David C. Evans the Balance of the Proceeds of the Murchison Geological Fund, in acknowledgment of the value of his researches among the Lower Palæozoic rocks. During the lifetime of his fellow-countryman, the late Dr. Henry Hicks, he was led to study the complex geology of parts of Western Carmarthenshire, and in 1906 he brought his labours in the St. Clears district to a very successful issue, as shown by his exhaustive paper in our Quarterly Journal. His natural enthusiasm in the pursuit of knowledge, particularly in the fields of geology and archæology, has in the past induced him to find time for original research in the midst of scholastic duties. We hope that in the near future his continued labours will produce equally good results.

In presenting one moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Dr. Lewis Moysey, B.A., the President addressed him in the following words:—

Dr. MOYSEY,—The Council has awarded to you a moiety of the Proceeds of the Lyell Fund in recognition of the value of your work on the fossils of the Derbyshire and Nottinghamshire Coal-field. Your contribution to a recently published Geological Survey memoir shows the wide range of the investigations which you have carried on in the intervals of a busy professional life. Not only have you added considerably to our general knowledge of the coal-field, but by the exercise of great patience and skill, and by using a novel method to obtain satisfactory material from a most unpromising matrix, you have discovered several rare as well as new forms of Crustacea, some of which you have described. You have also taken up with enthusiasm the study of those palæontological outcasts, *Palæoxyris*, *Vetacapsula*, and *Fayolia*. The Council anticipates with confidence further results from your researches, when you are freed from military duties and can resume your favourite studies.

The President then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to John Parkinson, M.A., to Professor T. G. Bonney, F.R.S., for transmission to the recipient, addressing him as follows:—

Dr. BONNEY,—The Council has awarded to Mr. John Parkinson a moiety of the Lyell Fund in acknowledgment of the value of his numerous contributions to geology, chiefly made in the intervals of arduous duties when conducting mining surveys in various parts of the world. He studied engineering at University College, London, and there acquired a sound knowledge of geology, which was afterwards increased at Cambridge. He at once proceeded to do excellent service to our science, and among the most important of his early petrological contributions may be specially mentioned his studies of the relations of the granites to the diorites in the northern and eastern parts of Jersey, and the light thrown by the hollow spherulites in the obsidian of the Yellowstone Park on the so-called 'pyromerides' of Boulay Bay. The value of his work on the Guernsey diorites must not be forgotten, nor of that in Northern Pembrokeshire and near Tintagel. He has touched with good effect on the lake-basins of the Canadian Rocky Mountains, and on the petrology of Ceylon and India. During more recent years he has also made notable contributions to our knowledge of the geology of Southern Nigeria, the Gold Coast, and Liberia. I shall be glad if you will convey this award to Mr. Parkinson, with the Council's best wishes for the continued success of his researches in the future.

In presenting the Proceeds of the Barlow-Jameson Fund to Mr. Joseph G. Hamling, F.G.S., the President addressed him as follows:—

Mr. HAMLING,—The Council has awarded to you the Proceeds of the Barlow-Jameson Fund as a mark of its appreciation of your geological work in North Devon, and as an encouragement to further research. For many years you have collected the rare fossils from the Culm and Devonian rocks of the county in which you reside, and have made numerous important observations on their stratigraphical arrangement. In the report of the excursion of the Geologists' Association to Barnstaple in 1910, you published a useful summary of your results in that district; and you have also contributed to the Transactions of the Devonshire Association and the Somersetshire Natural History Society. As one who has had the privilege of accompanying you in the field on many occasions, I have great pleasure in handing to you this award.

The President thereafter proceeded to read his Anniversary Address, giving obituary notices of Eduard Suess (elected a Foreign Member in 1877), and of the following Fellows: A. J. Jukes-Browne (el. in 1874), the Rev. Osmond Fisher (el. 1852), William Hill (el. 1885), H. J. Johnston-Lavis (el. 1875), F. W. Rudler (el. 1870), the Rev. J. M. Mello (el. 1865), W. Cash (el. 1873), A. R. Hunt (el. 1870), W. E. Darwin (el. 1881), L. V. Dalton (el. 1908), E. D. E. Isaacson (el. 1908), Baron Merthyr (el. 1867), and T. Stephens (el. 1873). He also referred to the death of Sir John Murray, K.C.B.

The President remarked that the progress of Geology depends on so many lines of research, that each specialist does well at times to pause and consider the relation of his own small part to the whole. He therefore reviewed some results of his study of fossil fishes in their bearing on stratigraphy. However necessary detailed lists of species of fossils might be for comparative work with sediments in restricted areas, he hoped to show that in dealing with broader questions names were really of small importance. Certain general principles had been arrived at, which would serve for all practical purposes. Each successive great group of fishes began with free-swimming fusiform animals, of which some passed quickly into slow-moving or grovelling types, while others changed more gradually into elongated or eel-shaped types. There was also a constant tendency for the primitive symmetry of the parts of the skeleton in successive members of a group to become marred by various more or less irregular fusions, subdivisions, and suppressions. Some of the successive species of each group increased in size, until the maximum was reached just before the time for extinction. These and many other more special inevitable changes had now been traced in most groups, and the various geological dates at which they occurred had been determined by observations on fossil fishes from many parts of the world. Even fragments of fish-skeletons, too imperfect to be named, were often therefore of value for stratigraphical purposes.

The Ballot for the Officers and Council was taken, and the following were declared duly elected for the ensuing year:—

Officers.—*President:* Arthur Smith Woodward, LL.D., F.R.S. *Vice-Presidents:* Henry Howe Bemrose, J.P., Sc.D.; Clement Reid, F.R.S., F.L.S.; Aubrey Strahan, Sc.D., LL.D., F.R.S.; and the Rev. Henry Hoyte Winwood, M.A. *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:* Bedford McNeill, Assoc. R.S.M.

The other Members of Council elected were: Professor Charles Gilbert Cullis, D.Sc.; R. Mountford Deeley, M.Inst.C.E.; John William Evans, D.Sc., LL.B.; Professor William George Fearnsides, M.A.; Walcot Gibson, D.Sc.; Sir Thomas Henry Holland, K.C.I.E., D.Sc., F.R.S.; Professor Owen Thomas Jones, M.A., D.Sc.; Finlay Lorimer Kitchin, M.A., Ph.D.; John Edward Marr, M.A., Sc.D., F.R.S.; Edwin Tulley Newton, F.R.S.; Robert Heron Rastall, M.A.; Professor William Johnson Sollas, M.A., Sc.D., LL.D., F.R.S.; J. J. Harris Teall, M.A., D.Sc., LL.D., F.R.S.; William Whitaker, B.A., F.R.S.

2. *February* 24, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Ashgillian Succession in the Tract to the West of Coniston Lake." By John Edward Marr, Sc.D., F.R.S., F.G.S.

The author has studied in detail the succession of the Ashgillian strata in Ashgill Beck and the adjoining tract. In Ashgill Beck the following sequence was detected:—

VALENTIAN.

			Thickness in feet.
ASHGILLIAN	Upper	Ashgill Shales .	about 50
	Middle	*Phacops mucronatus* beds .	16
		Ash	16
		White Limestone .	about 12
	Lower	*Phillipsinella* beds . . .	7

CARADOCIAN.

An account of the lithological characters and lists of the fossil contents of the various divisions are given, and confirmatory sections from Coniston Village to Appletreeworth Beck are described. A comparison is made with the beds of the Cautley district, previously described by the author. Some fossils which have not yet been found in the Lower Ashgillian of the Cautley district occur in the beds of that division at Coniston.

From a study of the fossils of the Coniston tract and of other areas in Britain and the Continent, it would appear that a twofold division of the Ashgillian strata which is of more than local value may be made. The lower division is characterized by the abundance of *Phillipsinella parabola*, and the upper by the profusion of *Phacops mucronatus*.

2. "The Radio-active Methods of Determining Geological Time." By H. S. Shelton, B.Sc. (Communicated by Professor W. J. Sollas, Sc.D., F.R.S., F.G.S.)

The radio-active method of determining geological time, while of great interest, is not of such certainty as to be independent of confirmation from other lines of investigation. The various radio-active methods, helium ratios, lead ratios, and pleochroic haloes are severally examined, and the various sources of uncertainty, general and particular, are pointed out. The most important general cause of uncertainty is to be found in the fact that mechanical and chemical changes of composition in minerals are the rule rather than the exception; and, in instances where constancy of composition throughout long periods of geological time is asserted, the burden of proof lies with those who make the assumption. The attempt to assess exact or even approximate times by means of lead ratios is premature and entirely invalid. At the same time, the weight of the evidence is such as to render it exceedingly probable, so far as radio-active evidence goes, that geological time must be reckoned at least in hundreds of millions of years. There is a high degree of improbability that the errors in the radio-active methods should always be errors of overestimation. The next step in the investigation of the time problem is to be found in a reversion to other lines of reasoning. The sea-salt methods, and those based on the thickness of the sedimentary rocks in particular, need careful reconsideration. Reference is made to a number of papers which show that the first of these is worthless, and the second based on a misapprehension of the nature of deposition. The argument from tidal retardation is still of value, as also is that from the evolution of carbonate of lime. To the author radio-active experiments come as a confirmation of views held on other grounds, but are not sufficiently important in themselves to be authoritative against the balance of the evidence derived from other lines of investigation.

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3. *March* 10, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Plants of the Late Glacial Deposits of the Lea Valley." By Clement Reid, F.R.S., F.L.S., V.P.G.S.

Large collections of plants from the Lea Valley deposits, already described, have been made by Mr. S. H. Warren, Mr. E. T. Newton, and Mr. Wrigley. The localities from which the plants were obtained are Angel Road, Hedge Lane, Ponders End, and Temple Mills. A list from Ponders End has already been given by Dr. Lewis; but the new collections include many unrecorded species, several of which have not previously been noted as British fossils. Although there are slight differences, the collections from all four localities are so similar as to leave no doubt that the deposits are contemporaneous. The whole assemblage points to a very cold climate, though perhaps not quite so cold as that indicated by the Arctic plants found at Hoxne, in Suffolk.

Among the more interesting novelties may be mentioned *Armeria arctica*, a species of thrift now confined to Arctic America, although it has also been recorded as a Pleistocene fossil from the continent of Europe by Dr. C. A. Weber. Leaves of *Salix lapponum* are also abundant, though this species does not seem to have been found fossil elsewhere. Some delicately-veined membranes, probably identical with the "petal-like objects" mentioned by Dr. Lewis, prove to be pods of the Alpine *Draba incana*. Other shorter forms are pods of a scurvy-grass, not yet satisfactorily determined.

The extinct forms are a new species of *Silene*, near to *S. noctiflora* but quite distinct, and a new *Linum* with large seeds. This latter apparently is closely allied to our cultivated flax (*L. usitatissimum*), of which the origin is unknown. It may be an ancestor of our common flax, but this latter is unknown far north, and will not grow with Arctic plants; the seeds of the two are perceptibly different. No large-seeded flax is now living in the Arctic regions.

2. "The Genus *Lonsdaleia* and *Dibunophyllum rugosum* (McCoy)." By Stanley Smith, B.A., M.Sc., F.G.S.

The present paper discusses the literature, structural characters and development, descent, classification, and distribution of the corals constituting the genus *Lonsdaleia*; it includes also a description of *Dibunophyllum rugosum* (McCoy). The author's reasons for including a description of *D. rugosum* in the paper are, first, the fact that the species was originally described by McCoy as *Lonsdaleia rugosa*; and, secondly, that considerable confusion exists between it and the fasciculate forms of *Lonsdaleia*.

Lonsdaleia is a compound member of the Clisiophyllidæ, and occurs both as fasciculate and as massive colonies. The chief distinguishing features of the genus are the wide extrathecal area, large dissepiments, complex central column, and horizontal and widely-spaced tabulæ. *Lonsdaleia* is an Avonian or lower Carboniferous genus, especially abundant in the highest horizons of that series (D_2 and higher beds). The earliest example is *Lonsdaleia prænuntia*, from the *Syringothyris* zone (C).

A number of species and local forms have been recognized and are described.

II.—Geologists' Association.

March 26, 1915. The following paper was read:—

"On the Structure of the Eastern Part of the Lake District." By J. F. N. Green, B.A., F.G.S.

The paper relates to the Lower Palæozoic rocks of the country between Ullswater, Shap, and Stile End. The author summarizes the literature dealing with the area, and the divergent views as to its structure. A great tuff band has been traced all over the district, and the succession worked up and down from it. This succession proves to be identical with that near the Duddon Estuary, but the andesites are mainly concentrated at two definite horizons. By the aid of this succession it is shown that, as in the district previously investigated, the Borrowdale Volcanics rest conformably on the Skiddaw Slates, and are unconformably overlain by the Coniston Limestone Series, the junctions being unfaulted. The existence of separate basic and 'streaky' groups is not confirmed.

An important basal sandstone and conglomerate belonging to the Coniston Limestone Series, but hitherto confused with the underlying volcanics, is described. The folding is discussed, especially powerful overfolds in the neighbourhood of Haweswater. Faulting is considered, with special reference to the lag-fault hypothesis.

III.—Edinburgh Geological Society.

February 17, 1915.—Dr. R. Campbell, President, in the Chair.

1. "The Evolution of the Cartography of Prince Charles Foreland." By W. S. Bruce, LL.D., F.R.S.E., and John Mathieson, F.R.S.G.S.

The paper described the evolution of the cartography of Prince Charles Foreland from its discovery in 1598 to its complete survey in 1909.

2. "Preliminary Account of the Geology of Prince Charles Foreland." By R. M. Craig, M.A., B.Sc.

The island is a mountainous ridge 55 miles long and from 6 to 8 broad, lying parallel to the west coast of the mainland of Spitzbergen, from which it is separated by Foreland Sound. The backbone of the island is formed by the steeply folded members of the Hekla Hoek formation, which is considered to be of Silurian age. On the west coast, in the neighbourhood of Glen Mackenzie, a coarse conglomerate occurs, which rests unconformably upon the Hecla Hoek rocks, and has been derived from them. This conglomerate represents the base of a formation formerly more extensive, and may possibly be of Devonian age. On the east side a series of conglomerates, sandstones, and shales occur, forming a narrow strip along the coast from Vogel Hook to Point Napier. These beds have yielded plant remains which show that they are of Tertiary age.

3. "The Pre-Glacial Platform and Raised Beaches of Prince Charles Foreland." By the late Angus M'Ewen Peach, B.Sc. (Communicated by Dr. B. N. Peach, F.R.S.)

The paper dealt with the physical features and glaciation of Prince Charles Foreland and West Spitzbergen, the pre-Glacial platform of marine erosion, and the post-Glacial raised beaches.

IV.—Liverpool Geological Society.

February 9, 1915.—W. A. Whitehead, B.Sc., President, in the Chair.

The following papers were read :—

1. "On the Simultaneous Crystallization of Minerals and its Significance." By H. W. Greenwood.

The author had collected from Halkyn Mountain, North Wales, specimens of calcite containing abundant small spangles of towanite together with wurtzite and malachite, which by their orientation showed clearly that they had been deposited from solution simultaneously with the calcite. This occurrence seems to be identical with that at Joplin, Missouri, U.S.A., recorded in a recent number of the *American Journal of Science.*

2. "On the presence of Tourmaline in Eskdale (Cumberland) Granite." By T. A. Jones.

Tourmaline has been found recently by the author in fair quantity near joint planes in the granite at Beckfoot, Eskdale. The mineral occurs in tiny specks and irregular and sometimes radiating aggregates often exceeding one inch in diameter. The granite itself has here features which distinguish it in some degree from the general mass of the intrusion. While a coarse micropegmatitic structure is prevalent, a much finer intergrowth of quartz and felspar, closely resembling that of the neighbouring Buttermere and Ennerdale granophyre, is occasionally well exhibited. A detailed description of the microscopic characters of the tourmaline was given, and specimens and photomicrographs shown in illustration.

CORRESPONDENCE.

FLINTS FROM THE SUFFOLK BONE BED.

Sir,—On p. 64 of a recently published paper, entitled "Flints" (Cambridge Antiquarian Society's Communications, vol. xviii), Professor McKenny Hughes, F.R.S., in dealing with the question of the sub-Crag flint implements I have discovered, makes the following statement: "Mr. Reid Moir has long been trying to test this question by observation and experiment, and has arrived at the conclusion that nature does not produce the forms in question. I must, however, say that I have failed to arrive at the same conclusion, but find that identical forms are produced under shore conditions which must have been similar to those under which the Suffolk Bone Bed was laid down." The definite nature of this statement induced me to pay a visit to the Sedgwick Museum, Cambridge, to see and handle these flints, flaked under present-day shore conditions, which were said to be "identical" with the sub-Crag specimens—a typical series of which I took with me for comparison. The examination of Professor Hughes' beach specimens showed me at once that none of the forms labelled "Bec d'aigle" bore any real resemblance to the rostro-carinate specimens recovered from the Suffolk Bone Bed, and represented obviously naturally broken flints which no one familiar with the sub-Crag specimens could ever regard as in any way similar, and the same may with confidence be stated of the beach examples purporting to represent other sub-Crag forms. I have no wish to say any harsh thing about Professor Hughes, for whom I entertain a great respect and regard, but I think he has been unwittingly misleading by his misuse of the word "identical" in his paper, and that it is not quite fair to Sir Ray Lankester and me—and liable to fog the issue—to label specimens in the Sedgwick Museum "Bec d'aigle" which bear no real resemblance to the sub-Crag rostro-carinate specimens.

J. Reid Moir.

12 St. Edmund's Road,
Ipswich.

GUIDE TO THE FOSSIL REMAINS OF MAN IN THE BRITISH MUSEUM.[1]

Sir,—I have read with much interest the review of the *Guide to the Fossil Remains of Man* in the British Museum, published in the Geological Magazine. Would it not be possible in the second edition to allow the Neanderthal man (as shown in fig. 12) a *scapula*? Such an omission is sure to lead to some silly mistakes on the part of the general public, for whom I presume this guide is written.

R. S. Newall.

Fisherton de la Mere House,
Wylye, Wilts.
March 15, 1915.

[1] See Geol. Mag. for March, 1915, p. 129.

OBITUARY.

PROF. JAMES GEIKIE, LL.D., D.C.L., F.R.S. L. & E., F.G.S.[1]

BORN AUGUST 23, 1839. DIED MARCH 1, 1915.

By the death of Professor James Geikie on March 1 geology in Scotland has lost its most prominent representative. He had been in failing health for some months, but the end was sudden and unexpected. In June, 1914, he had resigned his Chair in Edinburgh University, but as President of the Royal Society of Edinburgh, and Honorary Editor of the *Scottish Geographical Magazine*, he had much congenial work with which to occupy his time. His funeral took place on March 5 and was attended by a large and distinguished assembly, including representatives of the University, the Royal Society of Edinburgh, the Geological Survey, the Scottish Geographical Society, and many other scientific bodies. A full sketch of his scientific work and career appeared in the GEOLOGICAL MAGAZINE for June, 1913, pp. 241–8. Since that date he had delivered the Munro Lectures in Archæology at Edinburgh University, which he subsequently published as a book entitled *The Antiquity of Man in Europe* (Edinburgh, 1914). The previous year had seen the publication of his volume on *Mountains, their Origin, Growth, and Decay*. To the last he continued his earnest researches in physical and historical geology, and by his genial personality, wide sympathies, and inspiring example he was a powerful influence for research in the sciences of geology and geography, to which he had devoted his life.

J. S. F.

MISCELLANEOUS.

BERNARD H. WOODWARD, F.G.S., For. Corr. Z. S. Lond., Director of the Natural History Museum and Art Gallery, Perth, Western Australia.—We regret to announce the retirement of Mr. B. H. Woodward, after some twenty years, from the post of Director. Since his appointment the New Museum and Art Gallery have been erected, and the excellent arrangement of the entire collections is the result of his extensive knowledge, sound judgment, and untiring energy, the valuable art section in particular being entirely due to his initiative. His published reports on the fossil mammalian remains collected from the Mammoth cave of Western Australia, and upon the new and interesting zoological collections made in the colony, have added largely to the value and importance of this section of the Museum.

ERRATUM.—The Editor regrets that on Plate IV (*Schlotheimia Greenoughi*), in March Number, GEOL. MAG., some lines (viz. the incorrectly restored outline of the inner whorls) were erroneously added to the original drawing and not deleted before the proof was sent to press.

[1] For Portrait and Life see GEOL. MAG., June, 1913, pp. 241–8, Pl. IX.

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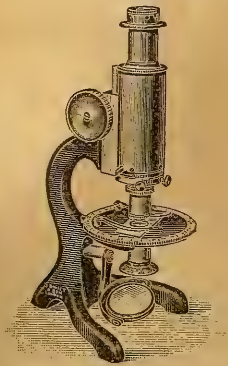

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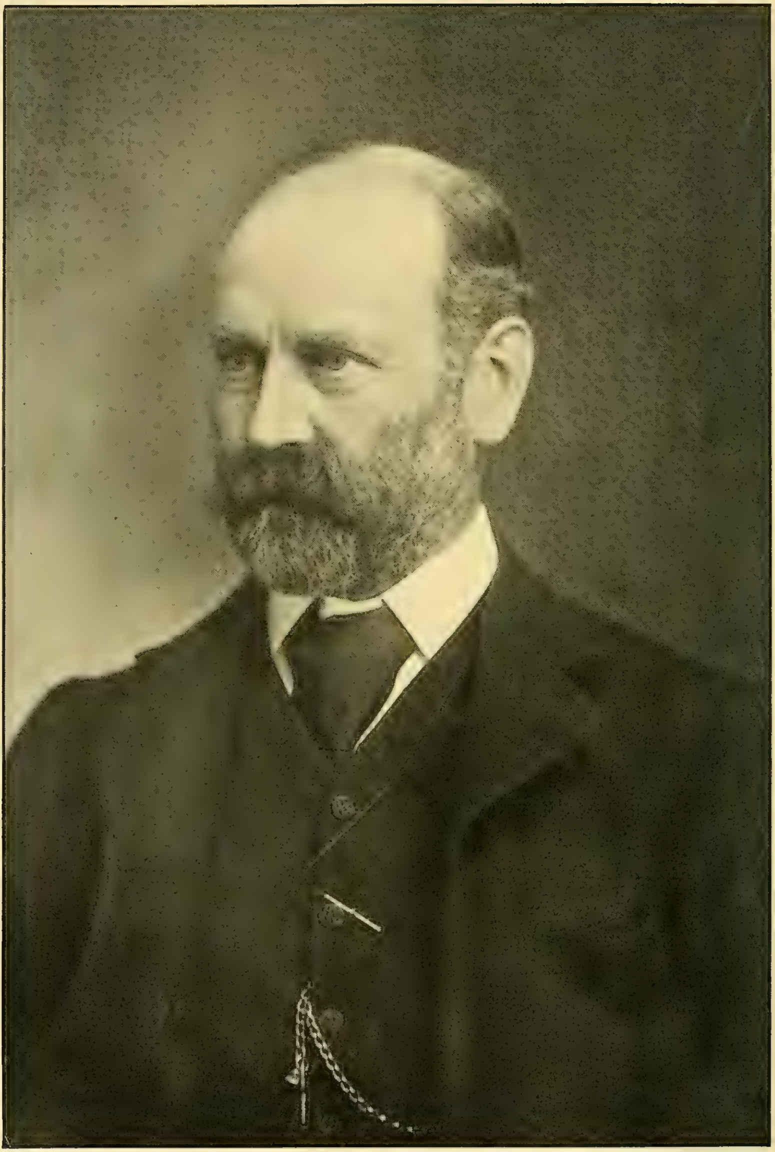

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(WITH A PORTRAIT, PLATE VII.)

THE records of the Geological Survey of Great Britain date back nearly as far as the first public recognition of geology as a science in this country.

Topographical map-making by the Ordnance Survey commenced in 1784, but it was not until about 1830, when the Director of Ordnance happened to see the excellent maps of the mining districts of Cornwall, the unaided work of De la Beche, that he wisely determined that the mineral delineation should be carried out upon the Ordnance Maps, a task which he induced De la Beche to undertake. Thus initiated, under the support of Major-General T. F. Colby, the Director of Ordnance, the Geological Survey commenced its career in Devon and Cornwall long before it had a local habitation and hardly a name. But through the influence of Government in 1837, Sir Henry De la Beche obtained a house in Craig's Court, Charing Cross, which became "The Museum of Economic Geology", and "The Mining Record Office" later on.

With but few assistants (until 1840) De la Beche traversed many thousand miles, hammer in hand, producing maps which have been the admiration of all who have had occasion to consult them, and thus laid the foundation of the Geological Survey of the United Kingdom and of the Museum of Practical Geology, which was opened in Jermyn Street by the Prince Consort in 1851. Although now shorn of its School of Mines and of its Irish Branch, this building is still the Museum of Practical Geology and the headquarters of the Geological Survey of Great Britain.

For nearly a century (1830–1915), from the date of its genesis under Sir Henry De la Beche, the Geological Survey has enjoyed the unrivalled advantage of a succession of distinguished scientific Directors, all of whom were experienced practical geologists, who had made their mark in the field as well as in the laboratory before reaching the chieftainship of the Royal hammerers.

Sir Henry De la Beche, the founder of the Survey, who passed away in 1855, was followed by Sir Roderick I. Murchison, whose name was already widely known, having been elected twice as

President of the Geological Society, and who left his mark as the author of *The Silurian System* and *The Geology of Russia.* Upon his decease in 1871, the office was filled by Sir Andrew Ramsay, who had been a member of the Survey since 1841, and local Director since 1845, his associates having been Sir Henry James, Dr. Oldham, Professor Jukes, Edward Forbes, A. R. C. Selwyn, Sir William Logan, John Phillips, and other famous geologists. Although only ten years Director-General he had been on the staff for forty years. On his retirement in 1881 at the age of 67, a third eminent Scottish geologist, Sir Archibald Geikie, became Director-General. He had already served on the Scottish Survey for twenty-six years, and at the time of his retirement in 1901 had completed forty-six years of service.

In the appointment of his successor consideration was paid to the special importance of the work of the modern science of petrography in the Geological Survey. For his eminent qualifications in this subject Dr. J. J. Harris Teall had been invited to join the Survey in 1888, and was selected as Director in 1901. Dr. Teall retired on the completion of his 65th birthday on January 5, 1914. (See Geol. Mag., 1909, pp. 1–8.)

Dr. Aubrey Strahan, the subject of this memoir, and the sixth Director since the establishment of the Geological Survey, has already attained a long and distinguished period of service and added largely to its Records, especially in the investigation of the British Coal-measures and the making of those splendid maps embodying the results of many years of careful and detailed field-work.

Born in London on April 20, 1852, Aubrey Strahan is the fifth son of William Strahan and Anne Dorothea Strahan (only child of Sir George Fisher). He spent his boyhood at Sidmouth, and received his early education at the Rev. W. T. Browning's school at Thorpe Mandeville, Northamptonshire. At 13 he was sent to Eton until 1870. During his school-days at Eton the Chemical Laboratory was built, and a prize for Chemistry (probably the first prize ever given at Eton for any branch of Natural Science) was won by him. A. Strahan proceeded to St. John's College, Cambridge, in 1870 (where his father had also studied). His interest in geology had been stimulated by the Rev. Osmond Fisher (his mother's first cousin), and his first course of the science was in Professor Bonney's lecture-room, where so many geologists received their early training.

A. Strahan graduated in 1875, and on May 12 of that year was appointed to the Geological Survey under Professor Sir Andrew Ramsay. He commenced his field-work in South Lancashire, and proceeded thence into Cheshire. After completing the surveying of the country around Chester he was engaged upon the Lower Carboniferous rocks of Flintshire with their metalliferous veins, the Silurian rocks of the Clwydian range, and the Trias of the Vale of Clwyd, a deep faulted trough of which the structure was then unknown.

In 1883, Strahan was transferred to Lincolnshire to assist in completing the last of the *Old Series* of 1 inch maps. In the two following years he was sent to the neighbourhood of Kendal and Sedbergh, and in 1886 revised the mapping of the Coal-measures, the

Cambrian and pre-Cambrian rocks, near Nuneaton, in order to make the corrections on the map rendered necessary by the discoveries then recently made by Professor Lapworth. Later on in the same year the mines of a part of Derbyshire were examined for the second edition of the Survey memoir on North Derbyshire.

In the latter part of 1886 Mr. Strahan commenced the 6 inch survey of the southern part of the Isle of Wight, and in 1887 he continued the work into the Isle of Purbeck. In 1891, it having been represented in the House of Commons by Sir Hussey Vivian (afterwards Lord Swansea) that the geological maps of the South Wales Coal-field were obsolete, the re-survey of that important area was commenced by Strahan and carried on continuously to its completion, save for two brief interruptions, one to the Isle of Man in 1892 and the other in the Cumberland Coal-field in 1894.

In 1886 Aubrey Strahan married Fanny Evelyn Margaret, daughter of the late Edward H. Roscoe.

In addition to his important work in the field as a Geological Surveyor, Dr. Strahan has contributed upwards of thirty-five memoirs to the publications of the Geological Survey between 1881 and 1915 (the titles of which appear at the end of this notice); but his scientific activities extended far beyond his official duties. For instance, he wrote an appendix to Major Conyngham's Pendulum Observations in India, and published numerous papers in the Quarterly Journal of the Geological Society, including two Presidential Addresses (1913–14). Since 1881 he has written many papers for the Geological Magazine (see list). In 1905 he prepared an important Report on the Coal-fields of Lancashire, Cheshire, and North Wales for the Royal Commission on Coal Supplies.

In 1913 Dr. Strahan was present at the International Congress at Toronto, and contributed the British Section to the Canadian volumes on the 'World's Coal Resources', published last year. As will be seen by the titles of his papers, his contributions to geological science were many and varied, but those which relate to the coal formations of Great Britain have a special importance in connexion with the unexplored areas which lie outside the known fields and await to be exploited in the future.

In 1875 he was elected a Fellow of the Geological Society, and has for many years served upon the Council. He filled the office of Treasurer (1909–12) and of President (1912–14). He was elected to the Royal Society in 1903 and has been on its Council (1909–10).

As a Fellow of the Royal Geographical Society, he was not only on the Council but acted as Chairman of the Research Department. He is an Honorary Member of the Chester Society of Natural Science and of the North of England Institute of Engineers. He accompanied the Total Eclipse Expedition to Vadso in 1896, and visited a section in the glacial deposits of Palæozoic age, also the raised beaches on the Varanger Fiord, and described them both at the Geological Society on his return. He served as President of Section C of the British Association at Cambridge in 1904, and in 1909 attended the meeting at Winnipeg, taking the opportunity to visit Vancouver. In 1910 he attended the International Geological

Congress in Stockholm and took part in an expedition to Spitzbergen. Three years later he attended the same Congress at Toronto as delegate from the British Government and as representative of the Geological Society and the Geological Survey. He was elected a Vice-President of the Congress, and received the honorary degree of LL.D. at the University of Toronto. On this occasion he took part in an excursion through New Brunswick and Nova Scotia. Dr. Strahan was made a member of the Royal Commission on Coal Supply in 1903 and furnished the Report on the Lancashire and Cheshire coal areas and on the concealed coal-fields of England and Wales (apart from the Midlands). In the same year he made a report to the Royal Commission on Arsenical Poisoning.

Out of the long list of famous British geologists who, by their labours in the past century, have so largely contributed to the building up of our science, a great part of them will also be found to have had a share in the making of the Geological Survey of this country. The present Director, Dr. Aubrey Strahan, must feel much gratification that in this task he also has contributed no mean share, both in the completion of its cartography and its numerous published memoirs, whilst as our leading authority on the great and important subject of the economics of our coal-fields he has made for himself a special name. He has carefully carried on his geological studies both at home and abroad, and possesses the experience won by long service and extended observation. But for the present sad war, which has disarranged all our peaceful enterprises, much attention would have been given at the present time by the Government to the anxious 'question of the hour', the extent and duration of our coal-supply.

We may sincerely congratulate the staff of the Geological Survey that in their present Director they have a man who has achieved his position by long years of earnest labour, and who is thoroughly conversant with their work and in sympathy with themselves.

List of Geological Survey Memoirs and Publications by Dr. Aubrey Strahan, M.A., F.R.S.

1881. Geology of Chester.
   Geology of Prescot: by E. Hull; third edition, with additions by A. Strahan.
1885. Geology of Rhyl, Abergele, and Colwyn.
1887. Geology of North Derbyshire: by A. H. Green and others; second edition by A. H. Green and A. Strahan.
1888. Geology of Kendal, Sedbergh, Bowness, and Tebay: by W. T. Aveline and T. McK. Hughes; second edition, revised and enlarged, by A. Strahan.
   Geology of the Country around Lincoln: edited and in part written by A. Strahan.
1889. Geology of the Isle of Wight: by H. W. Bristow; second edition, revised and enlarged, by C. Reid and A. Strahan.
1890. Geology of Flint, Mold, and Ruthin.
   Geology of the Country around Ingleborough: edited and in part written by A. Strahan.
1891. Geology of Mallerstang: edited and in part written by A. Strahan.
1898. Geology of the Isle of Purbeck and Weymouth.
   Supplement to the Memoirs on the Geology of Flint, Mold, and Ruthin.

1899. The Country around Newport.
1900. The Country around Abergavenny: with W. Gibson.
1901. The Country around Cardiff: with T. C. Cantrill.
1903. The Country around Pontypridd and Maestêg: with R. H. Tiddeman and W. Gibson.
1904. The Country around Merthyr Tydfil: with W. Gibson and T. C. Cantrill.
The Country around Bridgend: with T. C. Cantrill.
1906. Guide to the Model of the Isle of Purbeck.
1907. The Country around Swansea.
The Geology of West Gower.
The Country around Ammanford: with T. C. Cantrill, E. E. L. Dixon, and H. H. Thomas.
1908. The Coals of South Wales: with W. Pollard.
1909. The Country around Newport, second edition.
The Country around Carmarthen, with T. C. Cantrill, E. E. L. Dixon, and H. H. Thomas.
1910. Guide to the Model of Ingleborough.
1911. On a Deep Channel of Drift at Saham Toney; Summary of Progress for 1910.
1912. The Country around Cardiff: with T. C. Cantrill; second edition.
On a Boring for Coal at Ebbsfleet; Summary of Progress for 1911.
1913. On a Boring at Batsford; ibid.
1914. Notes on Sources of Temporary Water Supply in the South of England and neighbouring parts of the Continent.
On the Country around Haverfordwest: with T. C. Cantrill, E. E. L. Dixon, H. H. Thomas, and O. T. Jones.
1915. The Coals of South Wales, second edition: with W. Pollard; in the press.
On a Boring at Whittlesford; Summary of Progress for 1914; in the press.

LIST OF PUBLISHED PAPERS COMMUNICATED TO SOCIETIES AND JOURNALS APART FROM THE PUBLICATIONS OF THE GEOLOGICAL SURVEY.

1879. "On the Occurrence of Pebbles with Upper Ludlow Fossils in the Lower Carboniferous Conglomerates of North Wales": Quart. Journ. Geol. Soc., vol. xxxv, p. 269 (with A. O. Walker).
"On some Glacial Striæ on the Coast of North Wales": Proc. Liverpool Geol. Soc., vol. iv, p. 44.
1881. "On the Lower Keuper Sandstone of Cheshire": GEOL. MAG., 1881, pp. 396, 574.
"On the Discovery of Coal-measures under New Red Sandstone and on the so-called Permian Rocks of St. Helens, Lancashire": GEOL. MAG., 1881, p. 433.
1882. "On the Channel Tunnel": *Nature*, vol. xxv, p. 463.
1883. "On the Movements of Air in Fissures and the Barometer": *Nature*, vol. xxvii, p. 375.
1884. "The Denudations of North Wales": Proc. Chester Soc. Nat. Science, pt. iii, p. 38.
1885. "The Geology of Cheshire": Proc. Inst. Iron and Steel.
1886. "On the Glaciation of South Lancashire, Cheshire, and the Welsh Border": Quart. Journ. Geol. Soc., vol. xlii, p. 369.
"Notes on the Relations of the Lincolnshire Carstone": ibid., vol. xlii, p. 486.
"On the Rocks surrounding the Warwickshire Coal-field and on the Base of the Coal-measures": GEOL. MAG., 1886, p. 540.
1887. "On Explosive Slickensides": GEOL. MAG., 1887, p. 400.
1891. "On a Phosphatic Chalk with *Belemnitella quadrata* at Taplow": Quart. Journ. Geol. Soc., vol. xlvii, p. 356.
1895. "On Overthrusts of Tertiary Date in Dorset": Quart. Journ. Geol. Soc., vol. li, p. 549.

1896. "On a Phosphatic Chalk with *Holaster planus* at Lewes": Quart. Journ. Geol. Soc., vol. lii, p. 563.
"On Submerged Land-surfaces at Barry, Glamorganshire": ibid., vol. lii, p. 474.
1897. "On the Glacial Phenomena of Palæozoic age in the Varanger Fiord": Quart. Journ. Geol. Soc., vol. liii, p. 137.
"The Raised Beaches and Glacial Deposits of the Varanger Fiord": ibid., p. 147.
1898. "On the Revision of South Wales and Monmouthshire by the Geological Survey": Geol. Mag., 1898, p. 488.
1899. "On the Age of the Vale of Clwyd": Geol. Mag., 1899, p. 111.
"On an Abnormal Section of Chloritic Marl at Mupe Bay, Dorset": ibid., p. 319.
1901. "On the Passage of a Seam of Coal into a Seam of Dolomite": Quart. Journ. Geol. Soc., vol. lvii, p. 297.
"On the Origin of Coal": Geol. Mag., 1901, p. 29.
1902. "On the Origin of the River System of South Wales and its connection with that of the Severn and the Thames": ibid., vol. lviii, p. 207.
1904. Presidential Address to Section C of the British Association: Rep. Brit. Assoc. for 1904.
1905. Report on the Coal-fields of Lancashire, Cheshire, and North Wales, and on Concealed and Unproved Coal-fields, for the Royal Commission on Coal Supplies.
1906. "Investigation of Rivers" (with others): Geog. Journ., 1st Rep., 1908; 2nd Rep., 1909; 3rd Rep., 1910; 4th Rep., 1911; Final Report in the press.
1908. Appendix to paper on the Pendulum Observations in India by Major G. P. L. Conyngham: Survey of India, Professional Papers, No. 10.
1910. "Glacial Phenomena of South Wales": Rep. Brit. Assoc. for 1909, p. 475.
"The Geology of South Wales": Geol. Assoc., Jubilee vol., p. 826.
1913. Presidential Address ["On the Palæozoic Platform"] to the Geological Society of London: Quart. Journ. Geol. Soc., vol. lxix, p. 70.
1914. Presidential Address ["On Problems of Post-Glacial Denudation"] to the Geological Society of London: Quart. Journ. Geol. Soc., vol. lxx, p. 59.
"The Subdivisions and Correlation of the Pre-Cambrian Rocks of the British Isles": Internat. Geol. Congress, Twelfth Session (1913), Canada, *Compte-rendu* (1914), p. 339.
"On the Coal Resources of Great Britain": Internat. Geol. Congress, Twelfth Session (1913), Canada; "The Coal Resources of the World," p. 597.

II.—Differential Movement in East Anglia in Tertiary Times.

By P. G. H. Boswell, B.Sc., D.I.C., F.G.S., Imperial College of Science and Technology, South Kensington.

The sudden change of strike of the Chalk in South-East Suffolk, exceeded only in abruptness at the western limit of the London Basin, is accompanied by Tertiary phenomena equally interesting, and the occurrence of the Palæozoic platform at a small depth under the Chalk in the deep borings at Culford, Stutton, Harwich, and Weeley is, in this connexion, very significant.

Silurian or older rocks are separated from the Chalk at Culford, Stutton, and Weeley by a small thickness of Gault and Greensand only, while the rock met with in the Harwich boring, below 61 feet of the same beds, is believed by Professor W. W. Watts to have its closest parallel in that underlying the fossiliferous Cambrian rocks at the Spinney Hills, Leicestershire.[1] Whatever classification may be adopted for the beds reached in the boring at Saffron Walden, in North-West Essex, it is clear that a good thickness of Jurassic rocks is present here, and the Palæozoic floor occurs at a greater depth than in Suffolk and the London area. Dr. Morley Davies, in discussing the contours of the ancient platform under the East of England,[2] has suggested that the Mesozoic Rocks below Saffron Walden probably lie in a trough in the Palæozoic floor on the north-east of, and complementary to, Professor Kendall's main Charnian axis through Bletchley, etc. Dr. Davies indicates also the subsequent rise of the floor under Suffolk (contour map, loc. cit., pl. xxxiv). Mr. H. A. Baker, F.G.S., in working at the problem of the movements which have affected the London Basin,[3] arrived independently at a similar conclusion, and was, the writer believes, the first actually to state the opinion that a secondary Charnian axis of unrest, parallel to Professor Kendall's main axis, occurred diagonally across Suffolk and the Thames estuary. Mr. Baker finds evidence of instability along this axis, in the Mesozoic rocks north-east of Dover, as well as in the Lower Cretaceous rocks of North-West Norfolk. He considers that its north-westerly prolongation coincides with the Louth–Willoughby anticline, a conclusion with which the writer cannot agree. It seems more probable that the irregularity of the Chalk in North-West Norfolk is connected with this anticline. Three anticlines of Charnian trend would thus lie in echelon.[4]

Some years ago the writer ascribed the change in strike of the Chalk at several points in the East of England to a possible bending over the knee of the Palæozoic platform beneath, and the coincidence of strong through-valleys and breaches in the Chalk escarpment at the point where the strike varied (points which might very well be termed the "points of deflexion") was commented upon. A few examples of these points of weakness, due to a kind of anticlinal arrangement of the Chalk, are the Wash Gap,[5] the Little Ouse–Waveney through-valley, revealed by the Chalk surface-contours, and probably post-Eocene and pre-Pliocene in age, the group of convergent valleys in South-East Suffolk, the Hitchin Gap, the Goring Gap, etc.

Somewhat later, in his Presidential Address to the Geological Society, 1913,[6] Dr. A. Strahan touched upon the same question in drawing attention to the Medway Gap at the change in strike of

[1] Quart. Journ. Geol. Soc., vol. lxviii, 1912, Proceedings, p. cviii.

[2] Dr. A. Morley Davies & J. Pringle, "On two deep Borings at Calvert Station (North Buckinghamshire) and on the Palæozoic Floor north of the Thames": Q.J.G.S., vol. lxix, p. 308, 1913.

[3] In manuscript, a copy of which was kindly sent to the writer in July, 1914.

[4] Since the above was written Mr. R. H. Rastall has informed me that there is evidence in Cambridgeshire of the north-easterly movement of the Charnian axis through Sandy. See also *Geology in the Field*, pt. i, p. 140, 1909.

[5] Professor W. G. Fearnsides, whom I have to thank for discussing several points with me, mentioned that Dr. J. E. Marr has drawn attention to the coincidence of the Wash Gap and the change in the strike of the Chalk, but Dr. Marr tells me he has not yet discussed the matter in print.

[6] Q.J.G.S., vol. lxix, Proceedings, p. lxxv, 1913.

the Gault. Upon a further consideration of the contours of the base of the Gault in this area, in the light of fresh records, Mr. Baker, in the MS. cited, concluded that a strong fault probably existed in the Cliffe area, the effect of which was to give the base of the Gault a downthrow of about 200 feet to the east. From evidence yielded by Tertiary beds he concluded there had been later movement along this fault, the prolongation of the line of which met the Medway Gap on the south and the south-north bend of the Thames on the north. As a result of plotting the Chalk surface-contours of the London Basin, the writer independently obtained evidence of the same fault-line, this time traced southwards from Billericay in Essex, approximately along the sudden bend of the Thames, by Cliffe to the Medway Gap. The sub-Eocene Chalk surface has received a downthrow of about 100 to 150 feet to the east.

This convergence of opinion from many workers engaged upon different problems appears to indicate that with the gradual accumulation of data the time is ripe for preliminary generalizations. The latter will serve to show the directions in which further work and information are required.

For the purpose of discussing any possible Tertiary movements about an unstable axis passing under South-East Suffolk, we must suppose the thick covering of Glacial Drift to be stripped off. The Crag must next be imagined as removed, and the form of the Eocene surface revealed. Finally, the Eocene beds must be stripped away, and the form of the Chalk surface and distribution of the zones realized. Incidentally, it may be pointed out that the change of strike of the Chalk at the Little Ouse–Waveney through-valley, from northerly in Suffolk to north-north-westerly in Norfolk, is hardly indicated by the 'solid' geology as shown upon the Geological Survey maps, although it is at once apparent by the behaviour of the Chalk zonal outcrops.

The Chalk zones change strike in South-East Suffolk also. The dip-slope of the Chilterns, south-west of the area, where the Chalk is covered by Eocene beds, consists of the *cor-anguinum* zone, the strike being generally north-eastwards. At Bishop's Stortford the Reading Beds rest upon Chalk of this zone, but in North-West Essex and South Suffolk, while the Chalk zonal outcrops swing round northwards, the Eocene beds maintain their strike, overstepping the various zones until they rest upon *mucronata* Chalk in East Suffolk. Dr. A. W. Rowe and Mr. G. E. Dibley tell me that the Chalk of Grays in South Essex is a high horizon in the *cor-anguinum* zone, and the presence of the *Marsupites* zone in North-East Kent is significant. The higher Chalk zones (above *cor-anguinum*) must therefore V up the London Basin under the Eocene beds, but their change of strike occurs south-west of that of the latter in East Anglia.[1]

The Chalk surface-contours change direction also in South-East Suffolk, but cut across the zones as indicated by the map, Fig. 1; their

[1] Messrs. H. J. Osborne White and L. Treacher have shown that near Newbury, i.e. on the opposite side of Professor Kendall's Charnian axis, *Marsupites* Chalk again occurs under Eocene beds, and farther westwards the *A. quadratus* zone just appears.

strike therefore changes in an area north-east of the zonal deflexion. The statement has been made that there is a thinning in the Lower and Middle Chalk over the possible axis in Suffolk. The writer is unable to find any evidence for such attenuation. There is, however, an important change in the gradient of the sub-Eocene Chalk surface in South-East Suffolk. This is indicated by the way in which the contours crowd up both south-west and north-east of the critical area. Some figures may be quoted: Beccles to Lowestoft, 55 feet to the mile; Halesworth to Southwold, 27 ft.; Ipswich to Walton-on-Naze, 11 ft.; Hadleigh to Weeley or Clacton, 17 ft.; Thaxted

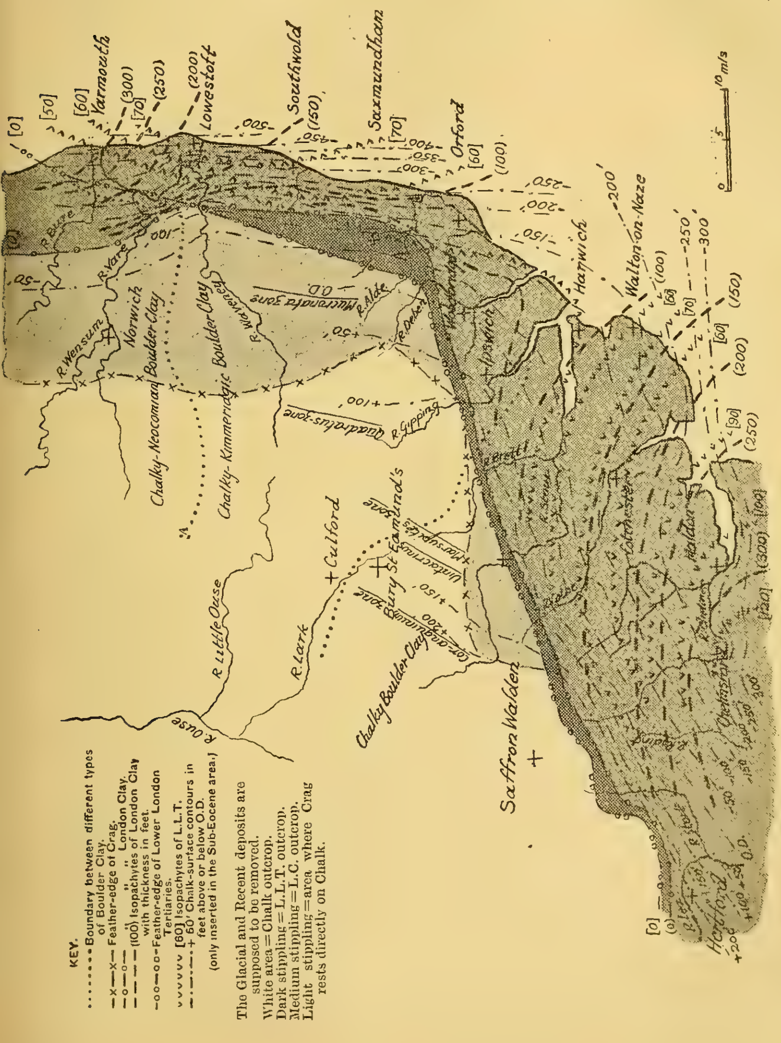

FIG. 1.—Sketch-map showing the distribution and thickness of the various geological deposits in East Anglia, with special reference to the anticlinal axis of instability.

to Chelmsford, 27 ft.; near Bishop's Stortford to Chipping Ongar, 36 to 44 ft. (On account of the small scale of the map a few local irregularities in the surface-contours have been smoothed out. The results are still reasonably accurate.) See Fig. 1, p. 201.

The north-westerly limits of the Lower London Tertiaries (the Thanet Beds and Reading Beds are not differentiated) and London Clay are also shown upon the map. Considering the former beds first, it will be seen that they overstep the Chalk zones and surface contours, their point of deflexion occurring near the Rivers Deben and Alde, again north-east of the change of strike last considered, namely, that of the Chalk surface-contours. Their thickness, as given by field evidence and well-borings, etc., has been plotted on the map and approximate isopachytes (lines joining points at which the thickness of the beds is the same) drawn. An interesting result follows in consequence of the thickening of these beds in both directions from the critical area. Owing to the thinning off of the beds by erosion to a feather-edge on the north-west,[1] these isopachytes are not normal to the strike, but take the form of curves thrown back along the feather-edge, but always convex to the critical area (except in this area itself, where, like the 50-feet isopachyte, they are convex to the south-east). Although the Thanet Beds are thinner in the neighbourhood of the Gipping Valley than elsewhere in the whole district, they show no evidence of shallow-water or shore-line conditions, as do the similar beds in the Sudbury area. Near their surface, however, they appear to yield evidence of planation, and contain lenticles of large wind-polished grains and small pebbles of flint and quartz. It would thus appear that the movement of uplift which spaced out the Chalk surface-contours was in abeyance in Thanetian times, but reasserted itself at their close. The thickening of the Thanet Beds north-eastwards and south-westwards would be accounted for by greater denudation over the central area.

The Reading Beds, which also thicken on each side of the point of deflexion, consist in the central area of sandy beds with subordinate lenticles of plastic clay. Both on the north-east and south-west, as far as we can rely upon records of borings, etc., they appear to consist of greater thicknesses of mottled clays with subordinate beds of sand. In view of the widespread shallowing in Reading Bed times, a movement which culminated all over the district in the formation of the bed of rounded black flint pebbles (variously referred to the Oldhaven Beds and to the basement-beds of the London Clay), care has to be exercised not to force the evidence.

Widespread and steady submergence took place during the deposition of the London Clay over the area. The great thicknesses of the deposit recorded in well-borings comparatively near to the feather-edge point to sedimentation under isostatic conditions. The northerly and westerly limit of the London Clay is indicated upon the map, and it is to be observed that the change of strike occurs north-eastwards of that of the Lower London Tertiaries. The boundary of the former deposit retreats from that of the latter in the neighbourhood

[1] It should be noted that this feather-edge constitutes the zero isopachyte.

of Saxmundham, but overlap occurs farther northwards, and in Norfolk the London Clay rests directly upon the Chalk. The same point is brought out by the distribution of the isopachytes of the bed. Like those of the Lower London Tertiaries, they are convex to a central axis (now north-east of that of the isopachytes of the Reading Beds), but their gradient is much steeper, and their form therefore better marked. It remains only to say that the London Clay near the point of deflexion does not reveal more evidence of shore action than that on the north and west. The thinning of the bed is due to erosion, and the surface is inclined to be irregular. It seems probable that slight uplift was taking place in the central area during deposition, and sagging and sedimentation on each side of it, but it was not until post-London Clay times that the movement became very marked.

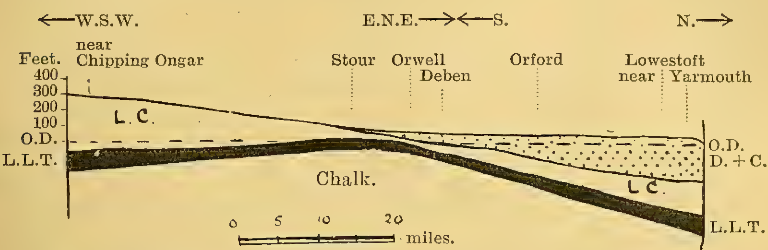

FIG. 2.—Section (to scale) across the axis of unrest in South-East Suffolk. The line of section is taken parallel to the Eocene boundaries. L.C. = London Clay; D. + C. = Drift and Crag; L.L.T. = Lower London Tertiaries; O.D. = Ordnance datum.

The unconformity of the Crag (considered as a whole) upon the Chalk and older Tertiary beds is worthy of note. At Mundesley and other places in North-East Norfolk, it rests upon the *lunata* zone (to retain an old name); in the neighbourhood of Norwich, upon the *mucronata* zone; in South Norfolk (Tharston, etc.), upon a very low horizon of the latter zone; and in East Suffolk possibly upon a high horizon of *quadratus* Chalk. In South-East Suffolk, however, the Crag boundary (see Fig. 1) osculates with that of the Eocene beds, or even passes a little way within it. In this area the Pliocene beds are seen resting upon Thanet Beds, Reading Beds, and, most frequently, London Clay, but not upon the Chalk. On passing into West Suffolk we find the Crag again resting upon bare Chalk of the *cor-anguinum* zone, e.g. at Stoke-by-Clare.

One of two things has therefore happened. Either the Crag boundary was once more or less parallel to that of the Eocene beds, and retreated as a result of erosion to its present position in pre-Upper Glacial times (pre-Glacial of the area under consideration), or the Crag was never deposited over part of the critical area. The latter case would yield evidence of the anticlinal form of the central area in Pliocene times; the former, of differential uplift in the area, resulting in greater erosion of the Crag, since the general level of the country in South-East Suffolk is as high as on the north-east and south-west, and the broad V in the Crag boundary is not due to a valley and geometry. Both considerations lead to the same conclusion of instability over the central area.

The Red Crag is believed to have been deposited in a number of land-locked bays which were being gradually forced northward by a series of earth-ripples, resulting in a general uplift on the south and subsidence on the north.[1] It may be merely coincidence that the Crag between the Orwell and the Stour shows evidence of much oscillatory movement; abundant pebbles, an impoverished fauna, and rolled and broken shell-fragments are characteristic.[2] The Crag deposits of Walton and Oakley on the one hand, and of Sutton, Butley, etc., on the other, while being drift-bedded, are richer in species, contain tiny and fragile shells, and show less evidence of disturbing conditions. It should also be remarked that the Boxstone Bed at the base of the Crags is confined to the central area.

The bearing of the form of the river-systems (which probably had their inception in Miocene times) upon the question will be discussed later.

The boundary between the two very different types of Upper Boulder-clay (Great Chalky Boulder-clay of S. V. Wood, jun.) in Suffolk has been inserted on the Map. This is adapted from Mr. F. W. Harmer's maps, with slight corrections, as a result of detailed mapping, by the writer.[3] We know that the general topography of Suffolk and Northern Essex was, in pre-Glacial times, much as it is now, and exercised a strong influence upon the ice-movements. This appears to be indicated by the boundary between the Chalky-Neocomian Boulder-clay and the Chalky-Kimmeridgic Boulder-clay in the lower part of the Waveney Valley, the latter occurring at Somerleyton, Burgh Castle, etc., and the former at Haddiscoe, etc.[4] The line of demarcation between the Chalky-Kimmeridgic Boulder-clay and the Chalky (or Chalky-Oxfordic) Boulder-clay in Suffolk is equally abrupt, and its position noteworthy, even if meaningless in the present connexion.

One of the best methods of registering secular movements taking place at the present day is provided by the behaviour of rivers. The following facts were not sought, but accumulated in the course of work upon the evolution of several East Anglian rivers.

Gradient-curves of all the East Anglian rivers have been plotted, and are seen to be of the usual logarithmic form. Rejuvenation, however, is revealed up to about the 50 ft. contour in the case of the Gipping, Stour, and Colne, by the introduction of a new and smaller logarithmic curve upon the lower portion of the old curve. In the case of the Chelmer and Deben, this rejuvenation extends to about the 25 ft. contour; it is hardly shown by the Alde, and does

[1] Mr. F. W. Harmer in numerous papers.

[2] See the writer, Proc. Geol. Assoc., vol. xxiv, p. 330, 1913.

[3] F. W. Harmer, *Geology in the Field*, pt. i, pl. iii, 1909; Trans. Norfolk and Norwich Nat. Soc., vol. ix, plate at p. 132, 1910; see also Proc. Geol. Assoc., vol. xxv, pl. xxiv, 1914.

[4] F. W. Harmer, loc. cit., 1910, p. 119.

not appear to be present in the Thames, Lea, Roding, Waveney, Norfolk rivers, and Wash rivers. Such rejuvenation may be due to many causes, but in the present instance most may be eliminated. The case is simplified by the fact that the whole district was subjected in post-Glacial times to a depression which turned the lower portions of the valleys into estuaries and caused them to be partly silted up. This depression, of at least 25 feet in the critical area, and considered to be 60 to 80 feet over the area from the Thames to the Wash, etc., by Mr. Clement Reid, successfully arrested the development of the rivers, the valleys of which were already overloaded with glacial débris.[1] Thus no release from damming has occurred; also rainfall has diminished, and there has been no increase in power or drainage area of the rivers, since late-Glacial times. Such capture as appears to have taken place is related only to the pre-Pliocene grain of the country and is certainly pre-Upper Glacial.[2] Moreover, the Colne is a beheaded stream, and yet shows the same amount of rejuvenation as the Stour, which has robbed it. The Gipping, with similar rejuvenation, is purely a dip stream. The Deben and Chelmer have largely increased their drainage area by piracy, but exhibit less change in gradient. It is submitted, therefore, that a strong probability exists that the rejuvenation is due to uplift.[3] When the results are plotted diagrammatically, Fig. 3 is obtained, and the evidence points to differential uplift in the area previously proved to be unstable.

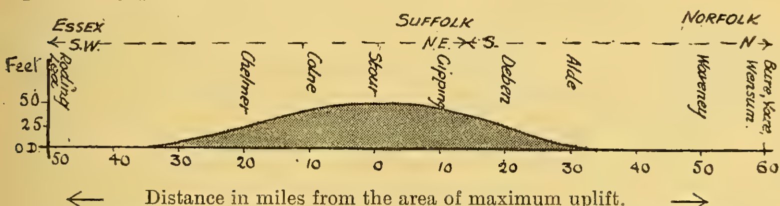

FIG. 3.—Diagrammatic representation of the variations in amount of the rejuvenation of East Anglian rivers. The heights to which rejuvenescence occurs are marked off vertically.

Summarizing, we may say that the outstanding feature is the manner in which the points of deflexion where change of strike occurs, and the axes producing them, moved north-eastwards. The Chalk zones are the first to change strike, then the sub-Eocene surface contours, next the Lower London Tertiaries, and finally the London Clay. The ripple then seems to have reached its farthest extent north-eastwards, and was subsequently reflected from the area under which the Palæozoic floor rises.

The river capture which has taken place has curiously had the effect in all important cases of throwing the drainage in towards the

[1] It was possibly this depression which buried the Neolithic skeleton and deposits found below tide-level near Walton-on-Naze by Mr. Hazzledine Warren.

[2] Q.J.G.S., vol. lxix, p. 612, etc., 1913.

[3] Rejuvenation up to the 50 ft. contour does not mean an uplift of 50 feet. A much smaller elevation would yield the result.

critical area (see Map, Fig. 1, p. 201). If such capture took place in Miocene times, it would appear to have been due to the hollow complementary to the ripple-crest which was at that time farther north-eastwards. Although the region was affected by widespread movements in Pliocene times, the crest may have tended to return south-westwards again as indicated first by the Crag outcrop and later (and farther south-westwards) by the rejuvenation due to uplift.

What was the impelling force driving the ripple so persistently north-eastwards, where did it originate, what are its effects outside this area, and what is the meaning of the rebound? These are theoretical considerations upon which it is better perhaps not to speculate at present, but which may open up fresh questions and lead to further investigation and accumulation of evidence.

Finally, it should be stated that the problem of attempting to prove the existence of an unstable axis was never embarked upon. The facts obtained in the course of working out other problems on each of the East Anglian deposits gradually fell into line.

III.—Tektite from British Borneo.

By Dr. F. P. Mueller, Basle (Switzerland).

It is well known that in various regions of Europe, Asia, and Australia dark pieces of glass are found which, in view of their peculiar shape and sculpturing, have attracted the attention of observers for a good many years. The name of *obsidianite* was given to these objects by R. H. Walcott. It expresses their resemblance in petrographic nature to obsidian.

Obsidianites are found in widely separated regions. It is evident from their physical and chemical properties that they belong to one petrographic class. However much they resemble one another there are points characterizing the specimens of each region. For this reason F. E. Suess has classified the obsidianites according to the main places of their occurrence, as *Moldavites*, *Billitonites*, *Australites*, and *Queenstownites*. In this view the origin of obsidianites is considered as a cosmic one, and excludes any comparison between them and obsidian; as an alternative the same author has chosen the name of *tektite* (τήκτος, molten), which he thinks is less open to objection.

The origin of tektites has been dealt with in numerous publications. It is their occurrence upon or in later deposits remote from recent volcanoes and manufactories, and their shape and sculpturing, that have been considered as the result of their cosmic source. Many doubts have been expressed as to these points. The extreme discordance between the petrographic characters of meteorites and tektites, chemically belonging each to the opposite ends of the rock series, was supposed to prove the impossibility of a meteoric origin for the tektites. Yet it is evident from a study of the analyses that there is no agreement between the chemical composition of tektites and of any similar known terrestrial rocks. It will therefore be hardly possible to think of any other than a cosmic origin for them.

The bibliography of tektites consists of numerous articles and monographs. Full lists are given in the following publications up to date of their appearance :—

1898. R. H. Walcott, Proc. Roy. Soc. Victoria, vol. xi, pp. 51–2.
1900. F. E. Suess, Jahrbuch K.K. geol. Reichsanstalt, vol. l, pp. 196–200.
1914. F. E. Suess, Mitteilungen Geol. Ges. Wien, vol. vii, pp. 54–6.

Attention must be drawn to the last of these three monographs. It gives full information on the chemical properties, and deals with all doubts that have been expressed on the origin of tektites. Further, it contains a description of a new kind of tektite, called Queenstownite.

It is the purpose of the present paper to describe a find of tektite from British Borneo, and specially to refer to those points which in view of the importance of this new occurrence are considered necessary.

The Tektites of the Sunda Archipelago.

The occurrences of tektites in the Archipelago, so far as known up to date, fall within an area that extends from the south-eastern corner of Borneo in a north-western direction to the southern portion of the Malay Peninsula, including the northernmost point of Java and the islands of Billiton and Great Natuna (Fig. 1).

The specimens from the Malay Archipelago are comparatively few in number, far fewer than the European and Australian tektites. Tropical vegetation and preponderance of sea within the above area might account for this.

Only in places where in consequence of mining operations the superficial deposits have been carefully examined, have a greater number of specimens been found, such as on Billiton Island and in the Malay Peninsula. Owing to the abundant occurrence at Billiton, the name of *Billitonite* has been assigned to all tektites from Malaysia.

It appears that the first Billitonite was found at Pleihari, in the south-east corner of Borneo, by S. Mueller, about the year 1836. A second specimen is known from the neighbourhood of one of the two Riam rivers, north of Pleihari. Two specimens are known from Mt. Muria, in Java, but only one appears to be an undoubted tektite. In 1879 P. van Dijk first described the Billiton occurrences, which were fully treated by R. D. M. Verbeek in 1897. In 1898 two specimens were recorded by P. G. Krause from Great Natuna. In 1909 a number of occurrences from the Federated Malay States was dealt with in the Geological Magazine by Mr. J. B. Scrivenor (p. 411).

The Tektites from British Borneo.

In February, 1913, the writer found four specimens of tektite in close proximity to Tutong Station, south-west of Brunei town. They were lying in a track, leading northward, and somewhat cut back into a small hill just behind the Chinese shops of the village. Apparently the stones were washed out of a white quartz sand, from a depth of one to two feet below the surface. This sand is part of a deposit that forms a well-marked terrace about 40 feet above sea-level along the coast of Brunei, especially near Yerudong, north-east of Tutong.

The sand deposit certainly does not belong to the present epoch, but is at least of diluvial age. It is evident, therefore, that the tektites, like those of Billiton and of the Federated Malay States, geologically speaking are also of diluvial age.

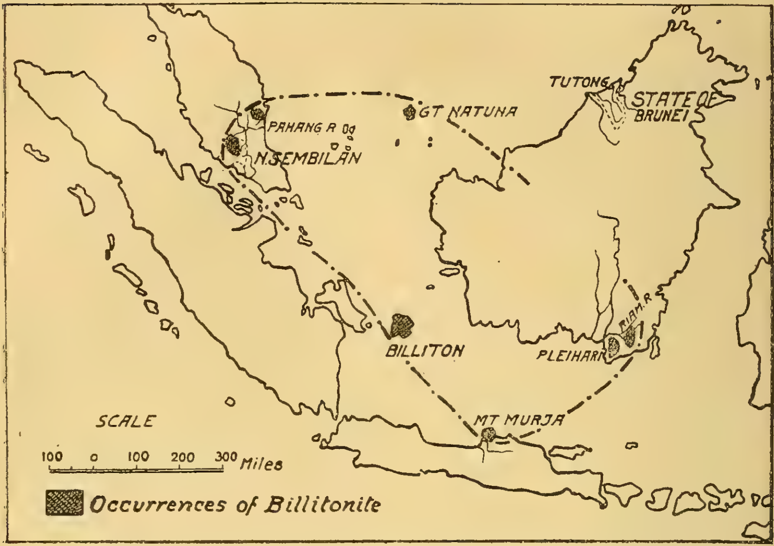

FIG. 1.—Map showing the area in which is included all known occurrences of Billitonite in the Malay Archipelago (dot and dash line).

The general characters of the Brunei specimens are shown in the following table (Table I):—

TABLE I.

No. of the Specimens	1	2	3	4
Size (mm.) . .	30/23/15	Diameter about 13	20/14/13	10/8/15
Weight (gr.) . .	11·72	5·37	5·87	0·5
Shape . . .	triangular	spherical	egg-shaped	triangular

The four specimens have the brilliant black lustre which is commonly characteristic of tektites. They are completely scored with very small marks, which makes their surface appear as if fine-grained. Closer examination shows the hemispherical moon-like hollows, often incompletely developed, which so commonly occur on Billitonites. Nos. 1 and 4 show a few deep, elongated pittings slightly wrinkled, rather smooth inside.

Physical properties.—The specific gravity is G = 2·457. The hardness is H = 6. The colour is dark-green brown. The index of refraction, measured on two optic prisms prepared from No. 2, was found $n = 1{\cdot}5097$ (Na). All sections revealed without aid of the microscope a fluidal structure.

Microscopic examination proved the specimens to be an almost pure glass. A very few, small, scattered vesicles were noted, while by aid of the strongest enlargement only a few indeterminable mineral particles were observed. Comparing the physical properties with those of Billitonites it is evident that they are almost identical.

Chemical composition.—The following analysis of a Brunei tektite was made by Dr. Hinden in Basle. In the first column is shown the percentage of each oxide, and in the second is given the molecular proportion.

TABLE II.

SiO_2	70·90	118·17
Al_2O_3	13·50	13·24
Fe_2O_3	0·32	0·20
FeO	5·47	7·60
CaO	2·35	4·20
MgO	2·45	6·12
Na_2O	1·46	2·35
K_2O	2·17	2·31
TiO_2 (estimated) .	1·00 (*ca.*)	1·25 (*ca.*)
MnO	trace	—
	99·62	155·44

The accompanying diagram (Fig. 2), p. 210, has been drawn in order to compare the Brunei tektite with the Billitonites and the best corresponding Australites. It shows the molecular proportions of the principal oxides plotted as ordinates, those of the silica taken as abscissæ of five analyses of Australites (Nos. I, IV, V, VI, VIII), two of Billitonites (Nos. 9, 10), and one of the Brunei tektite (No. **a**). The diagram is a modification of the basic portion of F. E. Suess' Table iii, 1914. The roman numerals correspond with those by which H. S. Summers (Proc. Roy. Soc. Victoria, vol. xxi, 1908) has marked the analyses of the Australites. The Arabic numerals are the numbers given in the same analyses as well as the analyses of the Billitonites by F. E. Suess, 1914, pp. 86–7 (see Table III, p. 211).

The examination of the diagram shows that the Australites and the Billitonites form two well-marked groups, their chemical variation being different in character. F. E. Suess (1914, p. 98) states as characteristic of the Billitonites the small percentage of alumina and the high percentage of alkalies. The rapid decrease of iron, magnesia, and lime is equally striking, while for the Australites these substances maintain an almost uniform position, diminishing very slightly only towards the acidic end of the series.

The Brunei tektite, as expressed by the diagram, though containing an almost equal quantity of silica as the Billitonites, shows little

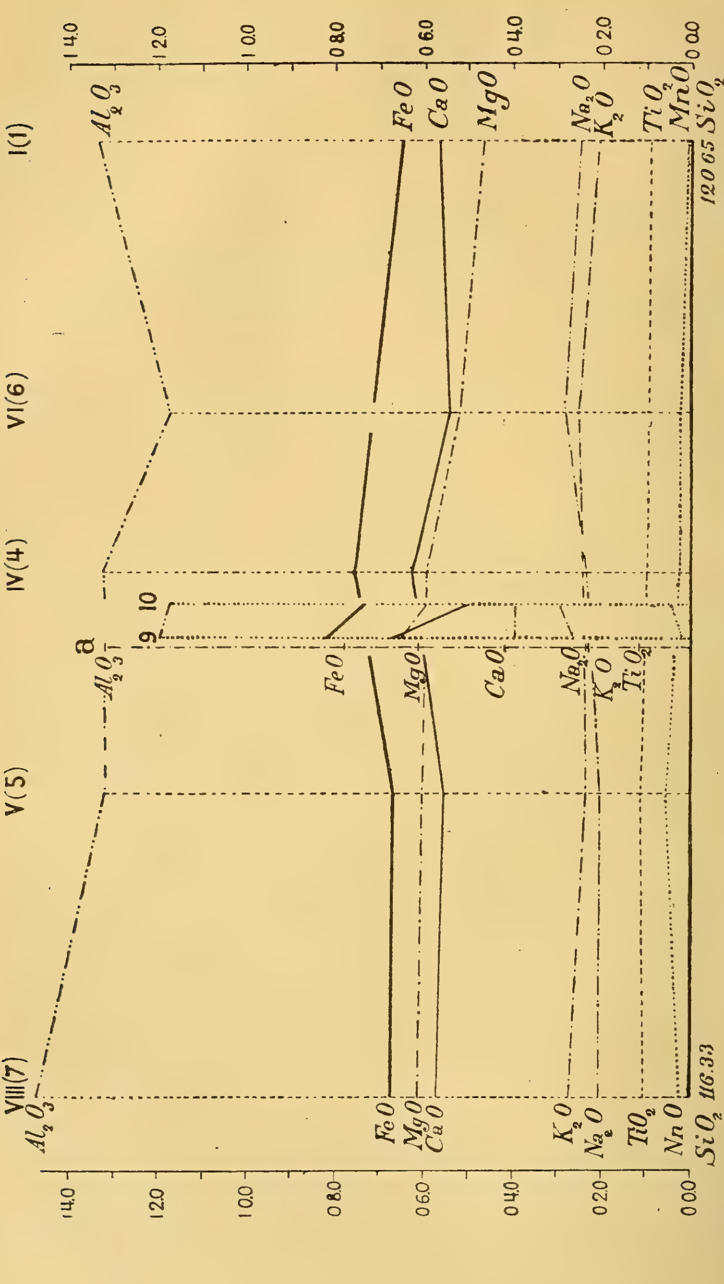

FIG. 2.—Diagram to show molecular variation in Australites (Roman numerals), Billitonites (Arabic numerals), and in the Brunei tektite (a).

agreement with the above characteristics and those of the latter group. Its alumina is as high as that of the Australites. The alkalies are low, but equally correspond with the position of the alkalies of the Australites. There is also more agreement between the amount of iron and magnesia of the Australites and the Brunei tektite than between the latter and the Billitonites. Lime is irregular and comparatively low in position.

It is known that the quotient from the sum of iron and magnesia divided by the sum of the alkalies, as well as the ratios of lime, potash and soda are the evidences that distinguish the tektites from all terrestrial rocks. Besides this, moreover, they also characterize each group of the tektites, as is clearly shown in the following table (Table III). It is evident from the diagram and also from this table that the Brunei tektites do not correspond chemically with the group of the Billitonites, but that there is much resemblance between them and the Australites.

Table III.

Number of the Analyses.		$\frac{FeO + MgO}{Na_2O + K_2O}$	$CaO : Na_2O : K_2O$
Australites . . .	I	2·5	6 : 2 : 2
	IV	2·8	6 : 3 : 2
	V	2·9	5 : 2 : 2
	VI	2·7	5 : 2 : 3
	VIII	2·6	6 : 2 : 2
Billitonites . . .	9	1·9	5 : 3 : 4
	10	2·2	7 : 3 : 4
Brunei tektites . . .	a	2·9	4 : 2 : 2

Conclusions.—The tektites from Brunei in British Borneo are, geologically speaking, most likely of diluvial age. Their shape and sculpturing show nothing peculiar. Their physical properties correspond with those of Billitonites. In their chemical composition there is much resemblance between them and the Australites.

IV.—Studies in Edrioasteroidea, VII. Morphology and Bionomics of the Edrioasteridae.

By F. A. Bather, M.A., D.Sc., F.R.S.

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THERE have now been described all the known members of the Edrioasteridae and the very similar genus *Steganoblastus*, as well as a genus apparently connected with the Agelacrinidae but presenting some remarkable features, namely *Pyrgocystis*. It is proposed in this and the following Study to deal particularly with the Edrioasterid organization, first considering what the known facts of skeletal structure imply as to the general anatomy and mode of life, secondly comparing the structure with that of other echinoderms, especially the Asteroidea. Although it may be necessary to refer to various facts that fall to be dealt with in future Studies, still the present seems a convenient opportunity for this general discussion, because of the recent publication by Mr. W. K. Spencer of the introduction to "A Monograph of the British Palæozoic Asterozoa" (Feb., 1914, Palæontogr. Soc. vol. for 1913), by Dr. J. F. Gemmill of his highly important memoirs on the starfishes *Solaster endeca* (1911, Proc. R. Phys. Soc. Edinburgh, vol. 18, pp. 174–91; and Feb., 1912, Trans. Zool. Soc. London, vol. 20, pp. 1–71, pls. i–v) and *Asterias rubens* (Oct., 1914, Phil. Trans., ser. B., vol. 205, pp. 213–94, pls. xviii–xxiv, and March, 1915, Proc. Zool. Soc. London, pp. 1–19, pls. i–iii), and by Dr. A. F. Foerste of some suggestive "Notes on Agelacrinidæ" (Sept., 1914, Bull. Sci. Lab. Denison Univ., vol. 17, pp. 399–486, pls. i–vi).

First, then, as to the internal organization and mode of life of the Edrioasteridae. It is clear from the position of the three openings—mouth, anus, and water-pore—on one face, that that face was directed upwards as in normal Pelmatozoa. Apart from that argument, the general resemblance of *Edrioaster* and *Dinocystis* to the undoubtedly sessile Agelacrinidae clearly indicates a similar position with regard to the sea-floor, even though the edrioasterids in question may not have been permanently attached. *Steganoblastus* obviously was fixed by a stem of ordinary pelmatozoan character, and by the mechanical stresses thus set up its theca has been modified so as to present a remarkable resemblance to that of a blastoid. How this stem originated is suggested by the parallel history of *Pyrgocystis*, in which we seem to trace the gradual elevation of the loosely and irregularly plated thecal wall, as seen in *Cystaster*, through the low turret of *P. sardesoni*, to the elongate stem-like turret of *P. grayae* and the more regularly plated turret of *P. ansticei* and *P. sulcata*.

Another criterion of Pelmatozoa is: "Food brought to the mouth by a subvective system of ciliated grooves, radiating from the mouth." The evidence for this in all Edrioasteroidea is the presence of radiating grooves protected by cover-plates, which plates are particularly well developed in Edrioasteridae and *Steganoblastus*, and apparently immovable over the mouth-region.

The only pelmatozoan character not yet mentioned is the presence of "an aborally placed motor nerve-centre". The presence of such a centre in *Steganoblastus* at any rate may be inferred from the stem with its lumen (Study V, 1914, p. 202) and from the axial folds similar to those which in many crinoids are known to have afforded passage for the nerves from that centre (Study V, p. 197). The possible relation of the lobes seen on the adapical face of *Edrioaster* to a chambered organ, such as that with which this nerve centre is connected in the crinoids, was discussed in Study II (1900, p. 202). It is, however, scarcely necessary to point out that a sessile or almost sessile form such as *Edrioaster*, without stem and without movable arms, had little or no need for such a motor nerve-centre. If we suppose the Edrioasteridae to be descended from forms with a more definite organ of attachment and with a moderately developed aboral nerve-system, we shall none the less expect to find that system considerably atrophied and leaving but slight traces. If, on the other hand, we suppose that the Edrioasteridae received their aboral nerve-system directly from the supposed anterior nerve-ganglion of some pre-echinodermal ancestor, *Dipleurula* or other, then again this will scarcely have been modified far in the direction of a motor centre. The same remark applies to any imaginable derivation of the Edrioasteridae from some echinoderm other than a Pelmatozoön, say a primitive Asterozoön.

The proof that the Edrioasteridae are Pelmatozoa in the full signification of that name has been laboured because the striking characteristic of this Family, more than of any other Edrioasteroidea, is just that strange resemblance to Asteroidea which suggested the second component of the Class name, and which will be fully discussed in the next Study.

Let us now consider more closely the Form and its relation to Fixation.

Edrioaster, *Lebetodiscus*, and *Dinocystis* have their rays curved like those of *Agelacrinus*, *Lepidodiscus*, and similar Agelacrinidae. This ensures a more or less circular outline of the theca or at all events checks any tendency to a star shape. That this curvature is secondary is an obvious conclusion from a comparison with the Agelacrinidae, from the facts of individual growth (Study IV, 1914, pp. 120, 121), and from the existence of the straight-rayed *Stegano-blastus*. Further, the oldest known Edrioasteroid, *Stromatocystis* from the Middle Cambrian, has straight rays. This last form is pentagonal, with a tendency to be stellate; but it cannot therefore be inferred that its as yet unknown ancestor was more stellate. The assumption of a pentagonal or star shape is a consequence of the straight outgrowth of the food-grooves. All that we know of the evolution of those structures in the earlier Pelmatozoa indicates that, in race-history as in individual growth, they stretched gradually outwards from the mouth, and by degrees impressed a radiate symmetry on every part of the theca as well as on the internal organs. *Stromatocystis*, as will appear in a subsequent Study, affords no evidence of descent from an ancestor in which the radiate symmetry was more strongly marked than in itself. On the contrary, for this Cambrian genus, as for all the Ordovician Edrioasteroids, the natural inference is that they are descended from a simple sack-like, irregularly plated pelmatozoön with no more than the beginnings of radiation seen in its food-grooves, which at first were but three in number. (See Treatise on Zoology, 1900, p. 11; Study I, 1898, p. 545; Study V, 1914, p. 201; and A. Foerste, 1914, op. cit., p. 412.)

It is generally admitted that radiate symmetry of this kind can only have arisen in a fixed form, and that in the case of Pelmatozoa the fixation must have been by the apical end. Such fixation was retained, or perhaps emphasized, in *Cyathocystis* and *Steganoblastus*. *Stromatocystis*, however, the only Edrioasteroid as yet known from

Cambrian rocks, was certainly not fixed, and can have had at most a loose and variable attachment. Between these extremes lie all the forms of attachment found in the Edrioasteroidea, differing from genus to genus, and even from species to species, according to the needs of the environment. Thus, evidence has been adduced to show that, in spite of Jaekel's contrary opinion, *Edrioaster* and *Dinocystis* were not actually fixed (Study II, 1900, p. 200; Study IV, 1914, p. 169). Direct evidence is wanting in the case of *Dinocystis*, but the indirect proof is the same as for *Edrioaster*, namely, that the fossils are never found resting on any hard surface, but have the apical face covered with shale or sand, which cannot have afforded a firm basis of attachment. It is by parity of reasoning that *Pyrgocystis grayae* and its Wenlockian successors are supposed to have been not fixed but inserted in a sea-floor of similar loose consistency, although *P. sardesoni*, in its firmer surroundings, seems to have been fixed.

The general situation of such Agelacrinidae as '*Agelacrinus*' sensu lato, *Hemicystis*, and *Streptaster*, upon the smooth hard surfaces of shells and similar objects, suggests a permanent fixation, and I can recall no very clear evidence to the contrary. Dr. Foerste, however, says (1914, op. cit., p. 407): "In all of the Ordovician species referred to *Agelacrinus* or *Lepidodiscus*, the animal evidently was capable of attaching itself to various objects for support, although this attachment was not permanent, and occasional specimens are found unattached." The nature of this temporary attachment is imagined by Dr. Foerste to have been essentially the same as that suggested by me for *Edrioaster* and *Dinocystis*. As explained in Study II (1900, p. 202), it is supposed that this was effected by an action comparable to that of a limpet or a sea-anemone or of any mechanical sucker. In all the species of Edrioasteridae the necessary elements of the theca were present, namely an apical concavity, a rigid frame, and a central area of flexible integument. We know, it is true, nothing of the muscles within the thecal cavity that may have raised up this central integument, but the radial muscles of the flexible-tested sea-urchin *Asthenosoma* indicate how readily the necessary muscles may have been developed. Another mechanism, however, may be conceived. If, as here maintained, the pores between the floor-plates of the subvective grooves led from podia fringing the grooves to ampullae within the thecal cavity, then the distension of the ampullae by influx of water through the hydropore, or by retraction of the podia, would exert hydraulic pressure on the walls of the theca and their flexible portions would be inflated. If now, the ampullae were contracted and all their contained fluid forced into the podia or even out through the hydropore, then the flexible parts of the thecal wall would necessarily be drawn inwards. Thus, if the thecal margin were resting on a sandy bottom, a vacuum would be created, with consequent sucker action.

In so far as this latter hypothesis helps to account for the presence of pores in the free Edrioasteridae, just so far does it fail to harmonize with their presence in the fixed *Steganoblastus* with its more rigid theca. Moreover, if the Agelacrinidae were attached by sucker action, their lack of pores prevents the extension of the hypothesis to them. It is, however, not only pores that are lacking, but also a plated apical integument, as may readily be proved by dissection or grinding either from above or from below, and by thin transverse sections (see further, W. K. Spencer, 1904, Proc. Roy. Soc., vol. 74, p. 43, l. 9, where for 'ventral' read 'dorsal'; also Foerste, 1914, op. cit., p. 409, § 13). Not that the absence of calcification would be the smallest bar to sucker-action, or to locomotion,[1] but it suggests that the animal rarely if ever relinquished its attachment.

The lobes of the flexible integument round the apical pole have been discussed more than once (Study II, 1900, p. 201; Study IV, 1914, p. 169). They have been found in all specimens of *Edrioaster* available for the prolonged preparation usually required; but this area is obscured in *Lebetodiscus*, and in *Dinocystis* all that can be traced is an occasional suggestion of an evagination (see text-fig. on p. 135, vol. 6, 1899) and foldings indicative of a stretched membrane (Study I, 1898, p. 546).

The number of lobes is five in the holotype of *Edrioaster buchianus*. In the specimens of *E. bigsbyi* the lobation is not so regular, but there are indications of the same pentamerism. Within the rounded margins of the lobes the integument is depressed, that is to say, withdrawn towards the interior of the theca. The lobes in *E. buchianus* were described as interradial, but in a form where the subvective grooves coil round from one radius into another, it is very difficult to decide upon the correct orientation of the apical face.

Whatever these lobes may mean, it is interesting to observe precisely similar structures, apparently with similar interradial position, figured by Jaekel in his *Thecocystis sacculus* (1899, pl. i, fig. 1 *b*) and described as an "Ansatzfläche" or "Anwachsungsfläche". In *Stromatocystis* also there is a pentagonal swelling with central depression round the apical pole, but the angles of the pentagon are prolonged in a distinctly radial direction.

This evagination may have had something to do with temporary fixation, but it does not reach as low down as the thecal periphery, and this function does not explain its quinquelobate structure. The only conclusions that can safely be drawn from the facts are that the shape indicates some rather firm internal organ or organs with quinque-radiate plan but without calcified skeleton. Beyond this all is pure speculation.

(To be concluded in our next Number.)

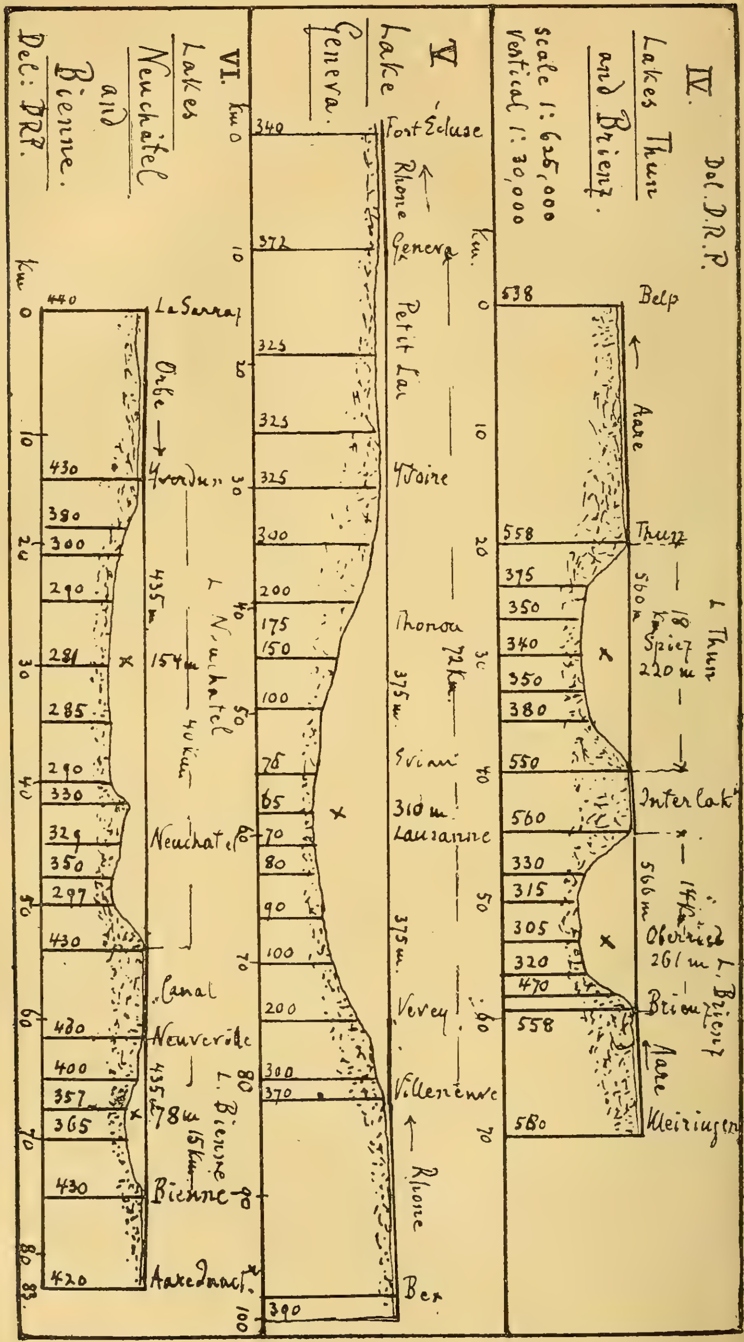
V.—The Zonal Lake Basins of sub-Alpine Switzerland.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

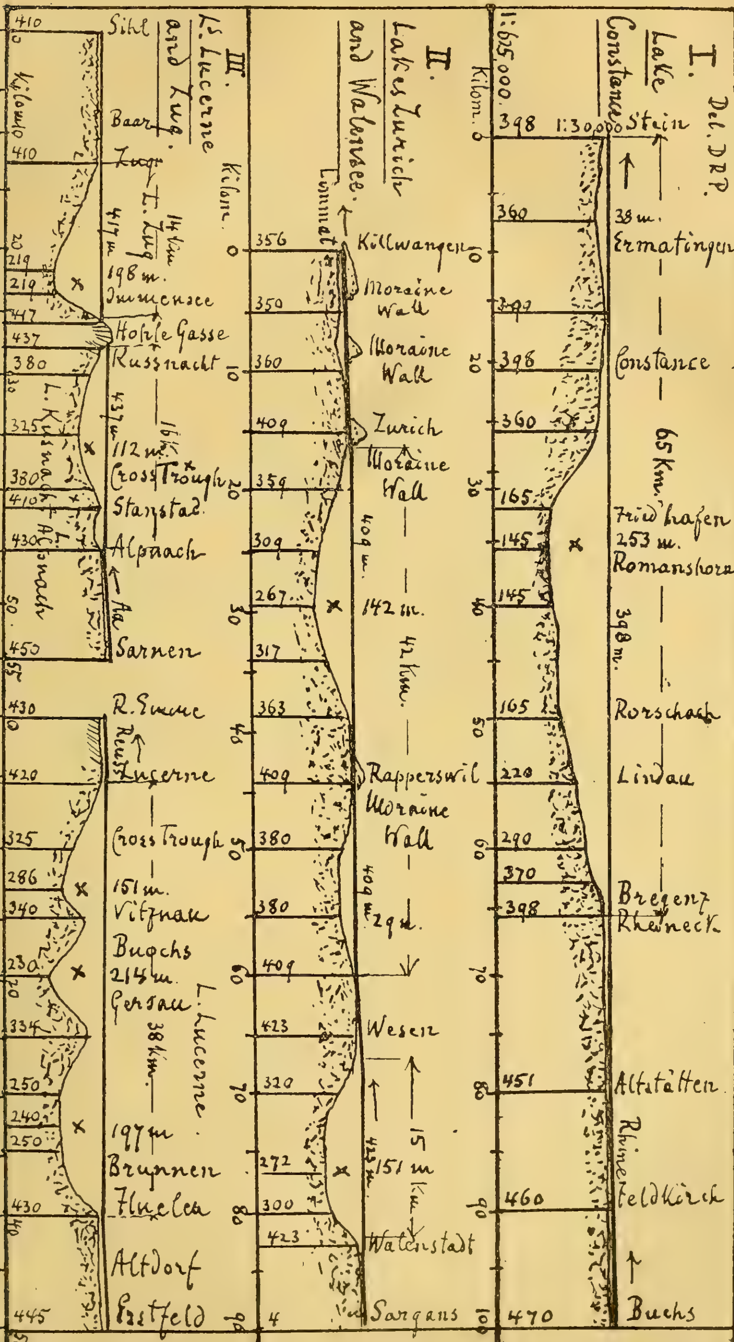
In two papers read before the Geological Society in 1904[2] I showed that the five principal lake basins of sub-Alpine Switzerland lie in a zone which is parallel to the Alps, and that this zone lies almost

[1] Cf. G. H. Parker, "The Locomotion of Actinians": Science, March 26, 1915, p. 471.

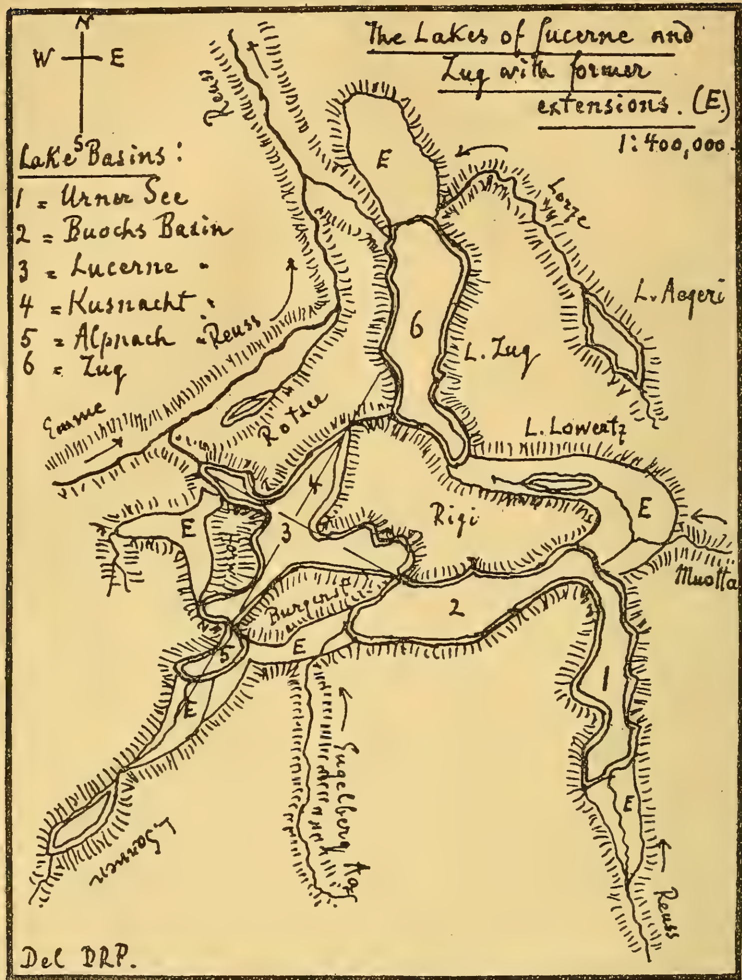
[2] Q.J.G.S., vol. lx, pp. 65, 316, 1904.

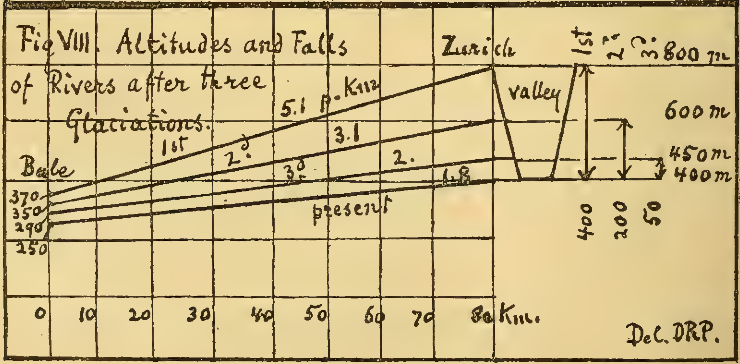


Sections. Figs. IV–VI. Sheet No. 2.



Longitudinal sections. Figs. I–III. Sheet No. 1.





Figs. VII, VIII. Sheet No. 3.

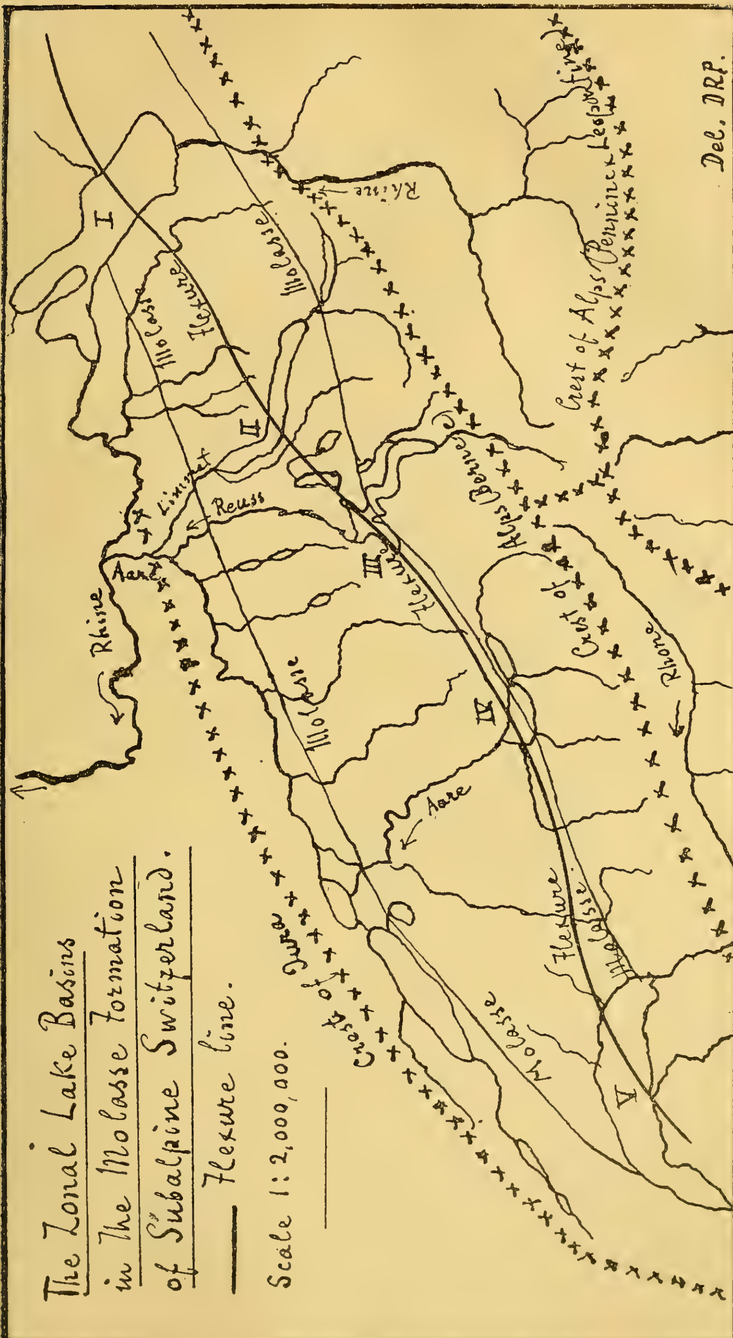


Fig. IX. Sheet No. 4.

entirely in the Molasse formation. The conclusions which I drew from these facts as to the age and origin of these basins having, since then, been confirmed by further evidence, it will not be without interest to return to the subject.

I. The Lake Basins.

The following table and the accompanying longitudinal sections, pp. 216–17, Sheets 1 and 2 (Figs. I–V), outline the salient features of the five zonal basins, to which are added (Fig. VI) those of the lakes of Neuchatel and Bienne because, although not zonal in respect of the other lakes, they present certain features common to all of them. All the dimensions are given in metric measure so as to correspond to the Swiss contour map from which the sections are plotted.

Lakes.	Former Length.	Present				
		Length.	Greatest Width.	Area.	Altitude.	Greatest Depth.
	km.	km.	km.	sq. km.	m.	m.
I. Constance .	100	65	12	539	398	252
II. Zurich . .	65	40	4	88	409	143
Walensee .	25	15	2	23	423	151
III. Lucerne .	50	38	3	94	437	214
Kusnacht .	22	16	2	20	437	112
Zug . .	19	14	4	38	417	198
IV. Thun . .	38	18	3	48	560	217
Brienz . .	24	14	2	29	566	261
V. Geneva .	110	72	10	582	375	334
VI. Neuchatel and Bienne	83	55	10	280	432	154

From the table and the sections it will be seen that all the lakes have lost at least one-third of their former length. At the upper ends the shrinkage is due to filling up by post-Glacial fluviatile alluvia, viz. mud, sand, and gravel; in the Rhone and Rhine valleys to some extent also by superficial deposits of loess borne by the Foehn, while at the lower ends it is largely the effect of banking by the post-Glacial deposits of rivers which discharge into the lake valleys more or less at right angles immediately below or above the present outflow of the lakes. The only exception is the Lake of Constance, which at its lower end lies entirely in a moraine basin, the shrinkage being due to moraine material retransported by the Rhine.[1]

A peculiar and very complex case is that of the Lake of Lucerne, *ante*, p. 218, which, as shown in Fig. VII, is composed of five, and,

[1] In the other lakes the fluviatile bars were formed by the following rivers: in the Lake of Zurich, by the Sihl; in the Walensee (an old branch of the Rhine), by the Linth; in the Lake of Lucerne, by the Emme, which, however, only deflected the Reuss instead of barring the lake; in the Lake of Thun, by the Kander; in that of Brienz, by the Lutschinen delta of Interlaken; in the Lake of Geneva, by the Arve; and in the Lakes of Neuchatel and Bienne, by the Aare.

including the Lake of Zug as a former integral part, of six distinct basins. Of these, three are longitudinal, and the other three transversal basins, the whole forming an irregular cross whose point of intersection marks the point of greatest depth. The original course of the Reuss was through the Schwyz valley along the northern base of Rigi and through the Lake of Zug, which course, in the lapse of time, it left to follow the southern base of Rigi and erode the defile immediately below Lucerne. Here it struck, and was deflected at right angles by, the River Emme, of whose junction with the Reuss, much larger and at a higher level than at present, the small Rothsee is a remnant. The effect of the Reuss changing its course was the lowering of the level of the Lake of Zug and the severing of its connexion with the Lake of Kusnacht. The plan shows the former extent of the intercommunicating basins in the trough between Rigi and Pilatus, in which the Burgenstock and Horw ridges appeared as islands. The shrinkage of the lakes amounts to more than one-half of their former aggregate length.

But the shrinkage of the lakes is not confined to their upper and lower ends, for, as shown in the sections, the lakes are gradually being filled up within their present areas, not only by the material transported and deposited in them by the main rivers, but largely by the delta deposits of the direct affluents of the lakes,[1] and in addition, by the lake deposits *per se*, the lake chalk or 'alluvion impalpable', which covers the lake floors in some cases to an unknown depth.

From these considerations it follows: (1) That, under the climatic conditions of the present time, the lakes are in course of being gradually filled up, and that this process would be much more rapid were it not for the great depth of their central portions and for their artificial preservation by canalization of the inflow and outflow. (2) That any lakes existing before the last glaciation were probably filled up and reduced to river valleys much more rapidly and completely than the present ones,[2] *à fortiori* because they were probably large, shallow, and often intercommunicating expanses of water rather than circumscribed lakes, in which the Alpine rivers, in their then erratic courses and subdivided channels, deposited material much more copiously than the rivers of the present time.

II. Lakes and Glaciations.

It has been affirmed by no mean authority[3] that the glaciers passed over, and deposited their moraines at the lower ends of the lakes and thus preserved them [*sic*]. Even if the present lakes had existed before, and had placidly endured throughout the Ice Age, the proposition of their being bridged by the glaciers, as it were, in

[1] The most formidable of these deltas is probably that of the Drance at Thonon (Savoy), which projects already 2 kilometres into the Lake of Geneva.

[2] Of this, striking evidence is afforded by the interglacial gravel beds near Zurich, the material of which, being strictly fluviatile, can only have been transported across the filled-up lake by a river.

[3] Heim, *Gletscherkunde*, 1885, p. 542; also Favre, *Récherches Géol.*, 1867, p. 210.

a single span, appears physically and mechanically impossible, the more so when the sequence of phenomena of a general glaciation is borne in mind. This sequence may be briefly stated as follows:—

Upon a general advance of the glaciers, the rivers gradually decrease in volume, velocity, and erosive energy, and the level of the lakes drops proportionately. When the glaciers reach the heads of the lakes, the latter, if they have not already been filled up by fluviatile deposition, gradually empty themselves through the natural outlets, and the supply from their drainage areas gradually failing, become reduced to meandering river channels and pools which, taking the temperature of the ice, freeze as the glaciers advance.[1] When these, after traversing the filled-up lake basins, become stationary, they deposit moraine walls round their terminal lobes, and in front of these walls flat glacis-cones of fluvio-glacial material are formed by the deposits of glacier streams flowing round and under those walls. When, lastly, the glaciers begin to melt and retreat, lakes form behind the moraine walls and gradually increase in length and size in the wake of the receding glaciers. At their lower ends the lakes at the same time find an outlet by a stream overflowing the moraine bar at its lowest point, generally at the margin and not in the middle of the bar, and thus the work of erosion begins both in the bar and in the glacis-cone, though the main stream often, as it were by caprice, erodes its bed round the edge, instead of through the cone. As the glaciers recede beyond the lake basins, the affluents of the latter, too, become active again, and thus new lakes are formed, probably different in size, depth, and altitude from their predecessors, only, in their turn, to be filled up again.

The diagram (Fig. VIII), p. 218, shows the average fall of the principal sub-Alpine rivers after the three glaciations, as evidenced by the river deposits—indicating the valley floors—of each period. It will be seen that the average fall, and therefore the erosive energy and carrying capacity, decreased with each glaciation and is lowest in the post-Glacial rivers of the present time.[2] It will further be seen that the rivers must have been flowing at much higher altitudes than at present, and that the same altitudes apply *ipso facto* to the lakes, the valley floor and lake level, e.g. at Zurich, having been 400, 200, and 50 metres higher than at present, and the altitudes in respect of the Lake of Geneva and the Rhone at Lausanne and Geneva being about the same. Thus each glaciation must have been followed by a very long period of erosion, the longest being that between the first and the maximum glaciation, during which the valleys were approximately eroded to their present depth, while after the maximum and the third glaciations the rivers had only to remove the products of

[1] For instance, a glacier, to traverse a filled-up lake basin 40 kilometres in length, like that of Zurich, at the rate of 0·3 m. = 1 foot per day, would require over 300 years, and in the case of the Lakes of Constance and Geneva double that time.

[2] The diagram refers to the area of the junctions of the sub-Alpine rivers between Zurich and Bale. In the Alpine valleys the former higher level of 400 metres would place the then valley floor, e.g. in the Linth Valley, on a level with the present Klöntal Lake, a hanging valley 400 metres above Glarus.

these two glaciations, which filled the valleys to the altitudes given above.[1]

It follows then (1) that the present lakes were formed during, and primarily in consequence of the last general retreat of the glaciers, in other terms towards the end of the Glacial Period; (2) that the lakes, like the main rivers which traverse them, were, at the time of their formation, at levels about 150 feet higher than at present, and that they gradually dropped to their present levels as the rivers eroded their beds more deeply in the Alpine valleys above and in the sub-Alpine valleys below them; (3) that the present lakes afford no criterion as to the extent or depth of previous—Interglacial or pre-Glacial—lakes which in any case must have been formed at much higher altitudes.

III. The Lakes and the Molasse Flexure.

The lakes having been primarily formed as shown in the preceding paragraph, it remains to explain the great depth of their central portions. In this connexion the theory of glacial erosion must be discarded, for a glacier, though it can scour, abrade, level, and polish, cannot perform the mechanical work of excavation. It has volume, but no effective velocity, and even its volume, not moving as a rigid mass, is rendered ineffective by its constant state of internal friction and deformation.[2] The depth of the lakes could be more easily explained by so many rifts at right angles to the trend of the Alps, were it not that the disruptive agency as the primary cause is wanting.

The only possible and logical explanation of the phenomenon must, therefore, be sought in a slow, simultaneous subsidence of the lake floors by a zonal bending of the Molasse formation in which the lake basins lie. A line drawn through the deepest points of the five lakes will be found to run parallel to the crest, and along the edge of the Alps, within but close to the western limit of the Molasse formation. This cannot be an accidental phenomenon; it constitutes, in fact, the syncline of the main flexure of the Molasse as shown in the plan (Fig. IX), p. 219.

Of this flexure the Molasse strata themselves afford conclusive evidence at various points. Renevier recognized its anticline as running from Savoy across the Lake of Geneva and thence north-east as far as the Canton of Appenzell (Lake of Constance), and deduced from it, though without reference to the lakes, "l'affaissement sur la lisière des Alpes," which corresponds to Heim's 'Einsenkung' or

[1] Some Swiss lowland Deckenschotter deposits at a somewhat lower level than the typical high-level ones led Mühlberg, Penck, and Brückner to assume a fourth glaciation (in the Tyrol even five), intermediate between the first and maximum glaciations; but those lower deposits may be, like that of Teufelskeller, near Baden, west of Zurich, due to local subsidence.

[2] On the other hand, a big glacier is indirectly a potent factor in valley-making and valley-shaping by the disintegrating action of frost and of the great differences between extreme temperatures on the mountain-sides as well as by its great lateral and vertical pressure. In this action lies obviously the *via media* between the extreme views *pro* and *contra* glacial erosion.

lowering along the base of the Alps as the latest effect of the raising of that chain in Tertiary times.[1]

The gradual lowering of the lake floors must have begun after the maximum glaciation, for in the Zurich Valley the older moraine was lowered with it, being now buried deeply below the present valley floor and overlain by the younger Interglacial and post-Glacial gravel beds. Thus the flexure must have continued throughout the last glaciation and reached its maximum of syncline at the time of the retreat of the glaciers, that is, towards the end of the Ice Age.[2]

As regards direct evidence of the Molasse flexure, my own investigations of the subsidence of the whole area between the Lakes of Zurich and Zuy have been described in previous papers, as have also the phenomena along the northern slopes of the Lake of Geneva.[3] These investigations fully confirmed Renevier's conclusions as to the flexure, which is indeed patent to anyone familiar with the general reverse dip of the Molasse banks, cliffs, terraces, and knolls, often conformably overlain by moraine and stratified gravel, between Lausanne, Vevey, and Clarens.[4] In the basins of Thun and Lucerne the conditions of the Glacial and Interglacial deposits are, owing to their closer proximity to the Alps, less clearly defined and somewhat more complicated than in the other basins. But here, too, there is abundant evidence of the bending process, and the more the subject is studied the more will it be realized that it is to the zonal Molasse flexure with its syncline in the deepest and central portions of the five lake basins that the lakes themselves chiefly owe their existence and their preservation.

VI.—The Genesis of Chiastolite; and its suspected Occurrence in Association with a Basic Intrusive.[5]

By Alfred Brammall, B.Sc. (Lond.), F.G.S.

(PLATE VIII.)

Introduction.—The following account of the alteration produced in shale by the sill-like intrusion at Marston Jabet, near Nuneaton, supplements the more general paper dealing with the intrusion as a whole. (See Geol. Mag., April, 1915, pp. 152–8, Plate VI.)

[1] Renevier, *L'Axe Anticlinal de la Molasse*, 1902; Heim, *Beiträge*, xxv, p. 475, 1891.

[2] The retreat of the glaciers must have been of very long duration, for in the Zurich sub-Alpine valley alone there are no less than four successive moraine bars across it, each of which is evidence of a long stage in the recession.

[3] A similar instance of zonal subsidence appears to be that of the Cleveland (Yorks) and the Black Combe (South-West Cumberland) "ancient glacier lake" districts, both of which, according to P. F. Kendall and B. Smith, were in pre-Glacial times at higher levels than at present (Q.J.G.S., vol. lviii, p. 471, 1902; vol. lxviii, p. 402, 1912).

[4] In 1906 an instructive section was exposed at Clarens at a junction of roads about 60 metres above the lake, showing about 20 metres of moraine with overlying stratified gravel dipping reversely like the rock strata in the immediate vicinity.

[5] A supplement to the author's paper on "The Intrusive Rock of Marston Jabet, Nuneaton, Warwickshire", which appeared in the April Number, pp. 152–8, Plate VI, 1915.

Normal Alteration Effects.—Though the alteration produced in the shales by the intrusive sheets is of the low grade and small extent usual for such intrusions, the effects include features hitherto recorded as occurring only within the contact zone around acid intrusives.

Shale taken from an horizon about 5 feet above the upper limit of the higher sheet shows no certain evidence of thermometamorphism beyond induration. Within the alteration zone proper (varying from 3 inches to 2 feet in vertical depth) the progressive alteration is as follows:—

1. Normal black shale, without pyrites.
2. Harder, fissile 'card' or 'biscuit' shale, with pyrites, developed mainly along the planes of separation.
3. A lighter-coloured, more compact rock: the shale has been partly bleached by the dissipation of the carbon content; the fissile character is less pronounced, the traces of the separation planes being pencilled out by pyrites.
4. A greyish, compact, sub-porcellanous rock, having the appearance of adinole.

The microscopic appearance of the two end terms of this series is described in the Appendix.

A suspected occurrence of Embryonic Chiastolite.—Of exceptional interest, however, are features observable in the shales which have suffered alteration either (1) as xenolithic slabs enclosed in the thicker sheets of igneous rock or (2) as the platform forming the floor of a sheet. Thin sections from the non-porcellanous zone of card-shale have the following features:—

1. The base is a pronounced reddish-yellow.

2. Granular pyrites is extremely abundant, as spheroidal aggregates with radial structure disposed mainly along the bedding planes.

3. Opaque (? carbonaceous) matter is present in considerable quantity.

4. The base has suffered a partial recrystallization, of an unexpected character. It is largely made up of a mineral giving rhombic, square, and polygonal sections, the boundaries of which are neatly pencilled out with dark opaque matter—possibly the excretive effect of crystallization, for the outer zone of each section is comparatively free from included opaque matter which, however, is frequently massed at the centre and less frequently at the corners or disposed along diagonals. These sections give aggregate polarization (1st order greys and yellows); hence, neither refractive index nor interference figure nor sign of birefringence is determinable for the original mineral, which has obviously paramorphed or been pseudomorphed.

No indication whatever of the crystal content of these altered shales is visible in the hand-specimen; yet it is difficult to avoid the conclusion that the crystal sections in question represent embryonic imperfectly individualized chiastolite, which by increment of alkali or possibly lime has been pseudomorphed to a schimmer aggregate.

Discussion of the Genesis of Chiastolite.—If this conclusion be correct, the occurrence of chiastolite is less restricted than is at present supposed.

Chiastolite is usually described (somewhat loosely) as a *variety* of andalusite; but though the two have the same empirical formula ($Al_2 O_3 . Si O_2$), the same crystal form, and the same (negative) sign of birefringence, the specific gravity of andalusite is constantly, and the degree of hardness usually, somewhat higher than for chiastolite—differences which might conceivably be an effect of higher pressure exerted on the parent rock at the time of its metamorphosis. But the inclusions of carbonaceous matter characterizing chiastolite are significant; such inclusions are essentially absent from andalusite, which, moreover, frequently occurs in gneissose and acid igneous rocks in such a manner as to leave no doubt as to its pyrogenic origin (whether from the fusion of aluminous xenoliths, or as a normal product of crystallization from a highly alumino-silicic magma, or otherwise, is immaterial to the present discussion). The assertion that chiastolite is merely a variety of andalusite may be true in this sense:—

(1) That the temperature range within which the orthorhombic silicate of alumina of empirical formula $Al_2 O_3 . Si O_2$ can be produced is very wide; and

(2) That if the silicate is initiated at a temperature nearer the lower than the upper limit—a temperature too low to dissipate (by oxidation) the entangled carbonaceous matter—the latter is constrained by crystallization to take up the diagonal orientation characteristic of chiastolite; and

(3) That if the silicate is produced at a temperature sufficiently high to dissipate the carbon and under pressure, the product is andalusite.

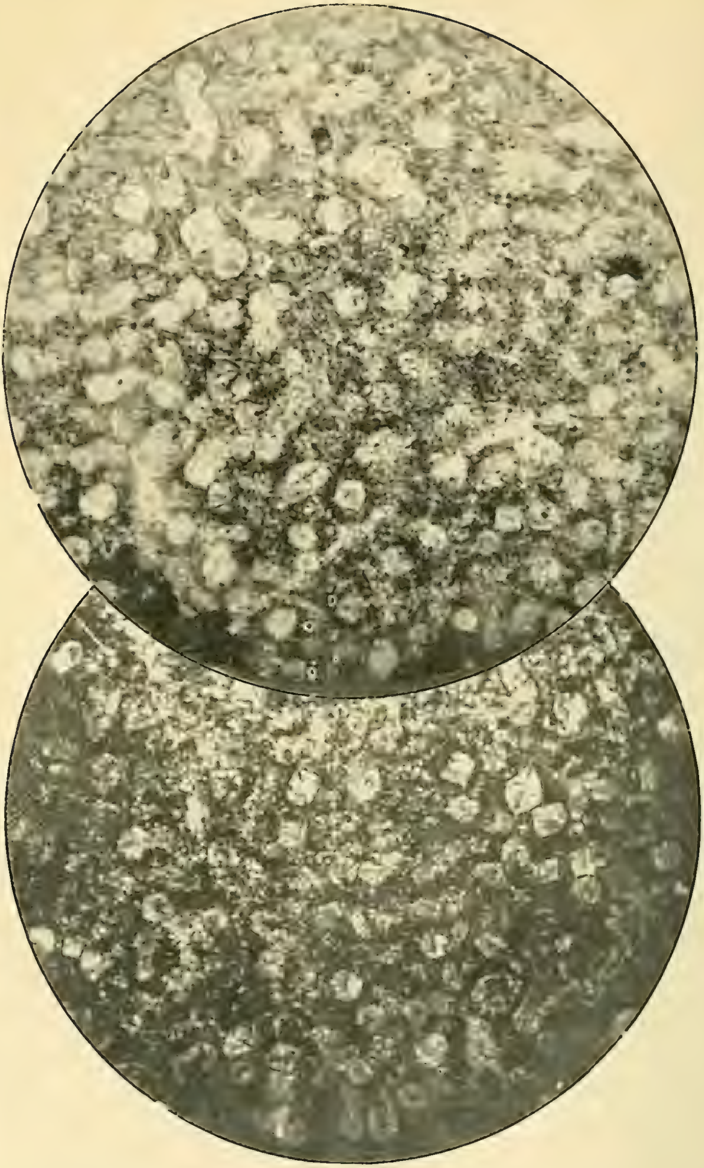
But if the upper limit of the 'chiastolite-andalusite' temperature range be passed at ordinary pressure by heating andalusite to 1320° C. this mineral paramorphs to sillimanite[1] (also orthorhombic but more acicular in habit and of positive birefringence); thus 1320° is the 'transition point' (at ordinary pressure) from andalusite to sillimanite, which may therefore be regarded as distinct 'phases', i.e. definite mineral species; and by analogy a temperature (much below 1320° C.) at which carbonaceous inclusions in chiastolite can be dissipated may be regarded as the 'transition point' from chiastolite to andalusite; and the question arises as to whether chiastolite *is* merely a variety of andalusite any more than andalusite is a variety of sillimanite.

Again, chiastolite is clearly a 'low temperature' product; and it is highly probable that the temperature range for its production is consistent with the presence of water, as such, at the time of, and possibly as essential to, the nativity of the mineral. Assuming only the mere *presence* of water, however, the production of the mineral in rocks of appropriate composition

(1) Depends upon the maintaining of a comparatively low temperature—within a restricted range; and

(2) Is effected in the presence of water (meteoric or juvenile) which may be essential either (*a*) as the sole mineralizer or (*b*) as the carrier of mineralizers more potent than itself—emanations or leachings from igneous magmas.

[1] W. Vernadsky, Bull. Soc. Min., vol. xiii, p. 256, 1890; Compt. Rend., vol. cx, p. 1377, 1890.



1

2

A. Brammell, Photo. Bale, Sons and Danielsson, Ltd.

Sections of altered Shale, showing embryonic crystals of Chiastolite.
Marston Jabet, near Nuneaton.

By virtue of (1) above, whatever be the chemical composition (acid or basic) of the igneous intrusion effecting metamorphosis, the temperature gradient, from the focus to the periphery of the aureole, should traverse a zone within which the temperature appropriate to the production of chiastolite is maintained for a shorter or longer time; hence, if heat alone (dry or moist) conditions the production of chiastolite in argillaceous rocks, the assertion (met with in most text books) that the occurrence of chiastolite is *restricted* to such rocks around *acid* intrusives is without obvious explanation.

If, however, the production of chiastolite is conditioned by heat and mineralizers carried by water, this restriction receives explanation at once, since the volatile content of acid magmas is notably higher than for basic magmas. The latter (a pneumatolytic) hypothesis, however probable, yet lacks definite experimental support, while on the other hand there is little to urge against the reasonableness of seeking chiastolite where its presence has not hitherto been recorded, that is, in argillaceous rocks altered by contact with basic intrusives, and if a search should prove occasionally fruitful such inconspicuous occurrences of chiastolite might even be regarded as special cases supporting the pneumatolytic hypothesis, in this sense: that as the volatile content of basic magmas is lower than that for acid magmas the purely pneumatolytic effect of the former will be less than for the latter, the 'chiastolite zone' will be narrower and less distinctive, and the mineral itself less perfectly developed—even only embryonic; and the occurrence described in this paper is urged as a special instance of the latter character.

Conclusion.—Similar occurrences elsewhere may have escaped detection for the following reasons:—

(1) The chiastolite is embryonic—too imperfectly developed to be conspicuous in hand-specimens of the parent shale; and may not have been sought for because its presence was not suspected.

(2) The zone of production either does not extend to the surface of the ground or is limited in width to a few inches; and even at greater depths the zone may still be very narrow and the mineral embryonic.

Appendix: Microscopic Features of Shales in Thin Section.

Shale No. 1.—An umber-coloured almost opaque base of finely divided matter, crystalline in part (since there is polarization, in low order greys and yellows) but of indeterminate nature; carbonaceous matter abundant; specks of sulphidic ore occasional.

Shale No. 4.—A light almost wholly transparent base, containing but little opaque (? carbonaceous) matter; pyrites conspicuous, as aggregates with radiate structure. Mainly composed of minute irregularly bounded grains of a crystalline substance showing fairly good relief and polarizing in 1st order greys and yellows. Irregularly distributed in the base are patches and strings of minute raggy flakes closely resembling sericite or paragonite.

EXPLANATION OF PLATE VIII.

Figs. 1, 2.—Photomicrographs of thin sections of altered shale parallel to bedding planes taken in ordinary transmitted light. Rhombic, square, and polygonal crystal sections can be made out in each of these figures, and the specific features of chiastolite are also distinctly discernible.

Note.—The possibility that these embryonic crystals (Figs. 1 and 2) may be *scapolitic* is not overlooked. Scapolite is occasionally developed as a contact mineral in argillites around basic intrusives, being restricted to a narrow zone at the contact. The optical features of such scapolite are often obscured by carbonaceous matter present as inclusions, while the mineral itself is often decomposed to a matted aggregate of mica-like flakes (colourless chlorite—'leuchtenbergite'). So far, therefore, the parallel between such occurrences of scapolite and the mineral now in question is complete; but the shape of the sections and the distribution of the carbonaceous matter give the latter a strikingly chiastolitic appearance, while the content of lime and alkali in the shales is much too low to favour the development of scapolite.

VII.—A Contribution to the Petrology of North-Western Angola.

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

(WITH A MAP, PLATE IX.)

1. Introduction.
2. Bibliography.
3. Notes on the Geology of North-Western Angola.
4. Ægirine-Riebeckite Granite from the Lower Congo.
5. Alkaline Igneous Rocks between Senza do Itombe and Bango (Loanda).

1. Introduction.

Last year I received from Colonel Freire d'Andrade a number of interesting alkaline igneous rocks, from a valuable collection made by him during an extensive exploration in North-Western Angola undertaken some years ago. Until recently our knowledge of the geology of that part of Africa was very scanty. Already in 1897 Cornet had described the western tongue of the Belgian Congo which separates the Portuguese provinces of Cabinda and Congo. Moreover, the occurrence of copper ores at Bembe and Senza do Itombe had attracted some geological attention, but it was not until Colonel Andrade's journey that any systematic geological observations were made over a large area of the territory. Since then a number of prospecting expeditions have been conducted by J. J. MacHugh, the results of which serve to extend our knowledge to the south of the area described by Colonel Andrade. In view of the inaccessibility of much of the literature dealing with Angola, it may be interesting, before giving petrological details of some of the rocks, to present in English a short sketch of the geology of part of Portuguese Congo and Loanda, embodying the observations made by Andrade and MacHugh.

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2. Barradas, J. F. "Diario relatorio sobre a formação geologica encontrada durante a recente expedição através da Quissama e parte da região do Amboim e Libolo por J. J. MacHugh, 1909": Revista portuguesa colonial e maratima, No. 149, pp. 219–26, 1910.


FRENCH CONGO
Mayambe
Belize
CABINDA
Diabase Intrusions
Ncuta
Diabase Intrusions
Granite Intrusions
Diabase Intrusions
RIVER CONGO
BELGIAN CONGO
Landana
Cretaceous
Matidi Schist
Bembizi Beds
Boma Granites
Boma
Matidi
Banana
Noqui
Riebeckite Granite
R. CONGO OR ZAIRE
S. Antonio
Crystalline Limestones
S. Salvador
PORTUGUESE CONGO
Mpozo R.
Diabase
S. Joao
ATLANTIC OCEAN
R. Mbrige
Bembe Copper
Ambrizette
Kiballa
R. Loge
Nordmarkite
Ambriz
LOANDA
Sketch Map to illustrate the
GEOLOGY
of
NORTH WESTERN ANGOLA
by
ARTHUR HOLMES
Scale of Miles
10 0 50
LOANDA
Bango
R. Quanza
Senza do Itombe
Copper
Dondo
Alluvium
Tertiary Igneous Rocks
Eocene and Miocene
Cretaceous
Lower Karroo (?)
Silurian (?)
Archæan Complex
Diabase Intrusions
12° 13° 14° 15°
4° 5° 6° 7° 8° 9° 10°

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5. Cornet, J. "Géologie du Congo occidentale": Bull. Soc. Belge Géol., vol. xi, 1897.
6. MacHugh, J. J. "Reconhecimento ás minas de cobre do Zenza e do Bembe": Boletim de Agricultera—Governo geral da provincia de Angola, No. 6, pp. 265–9, 1909. See also J. F. Barradas.
7. Sousa, Pereira de. "Contribution à l'étude petrographique du nord d'Angola": C.R., vol. clvii, p. 1450, 1913.
8. Studt, F. E. "An Outline of the Geology of South Central Africa": Trans. Geol. Soc. S. Africa, vol. xvi, pp. 85–7, 1913.
9. Voit, F. W. "The Copper Deposits of Senzo do Itombe": Zeit. Prakt. Geol., p. 86, 1899; p. 353, 1902.

3. Notes on the Geology of North-Western Angola.

As indicated in the adjoining sketch-map, this part of Africa is characterized by three well-marked belts. The middle belt consists of a complex of gneisses and schists through which later intrusions, chiefly of granulitic granite with their attendant pegmatites, and of diabase, have penetrated. On this typical Archæan basement lie the Cretaceous and Tertiary beds of the coastal plain, and the old sedimentary formations which form the plateau of the interior.

Archæan Complex.—The oldest rocks of the territory, as elsewhere in the equatorial coast lands of Africa, are represented by schists, crystalline limestones, and sediment gneisses. Between the Tertiary beds of Landana and the French frontier at Mayambe, mica-schists, quartzites, quartz-epidote and epidote schists, and felspathic sediment (arkose) gneisses occur, with local bands of chlorite, hornblende, and hæmatite schists. Generally underlying the schistose rocks, but showing intrusive contacts in places, is a vast foundation of gneissose granites (primary granite gneisses of some authors) with interfoliated hornblende gneisses and amphibolites. The gneissose granites contain albite, oligoclase, and microcline, an association of felspars which is highly characteristic of the oldest granites throughout Africa. The lithological features of these gneissose and schistose rocks justify one in assigning them to the Archæan. Intrusive into the fundamental complex is a series of granulitic granites which are well exposed near Ncuta. Diabase dykes and sills which have suffered uralitization are found near Ncuta and Belize. They appear to be younger than the Palæozoic sedimentary rocks which appear near the French frontier, for similar diabase intrusions penetrate the old sedimentaries where they cross the Congo to the south-east. In this district, the Belgian sphere of the lower Congo, Cornet has recognized a similar succession. The Matadi schists are intimately associated with gneisses and amphibolites, and the whole complex is intruded upon by the Boma granites.

To the south of the Congo, again in Portuguese territory, mica-schists and quartzites occur along the road from Noqui to San Salvador. The schist series differs in this locality from its northern continuation in the comparative rarity of epidote-bearing rocks, and by the appearance of numerous bands of crystalline limestone. Near the River Mavumi gneissose granites are exposed. Granulitic granites are found just south of the Congo, similar in structure to the Boma granites, and remarkable for their high content of albite. In many places they are injected in sheets between crystalline limestones and other members of the schist series, and in the former, interesting contact minerals, such as chondrodite and diopside, have been developed. Syenites occur between Tombo and the River Lalu. At kilometre 16 on the Noqui - San Salvador road the limit of the albite granites is reached, and at this point Colonel Andrade found a variety containing a relatively high percentage of riebeckite, accompanied by ægirine. This rock, a splendid example of an interesting type of which very few occurrences are known, is described in detail below. It illustrates Harker's view[1] that alkaline rocks, and especially unusual types, tend to occur on the margins of igneous provinces.

Between Bembe and the coast at Ambriz, the schists and gneisses are not seen until Kiballa is passed, after which they continue to the coastal belt, where they disappear under a thin narrow band of Tertiary formations. Near the mission station of San João intrusions of diabase are found, the only examples of this rock met with in Portuguese territory south of the Congo. At kilometre 19 between the coast and Bembe the western peripheral phase of the granulitic granites is represented by a fine-grained reddish rock which is described by M. de Sousa as a *nordmarkite*.[2] It therefore seems to differ from the ægirine-riebeckite granite already mentioned only in the possession of arfvedsonite in place of riebeckite.

Palæozoic Rocks.—Lying unconformably on the basal complex is a system of old sedimentary rocks which includes two distinct series of formations. In the enclave of the Belgian Congo Cornet has described a lower series which he calls the Bembizi Beds, including conglomerates, calcareous sandstones, shales, and slates, and an upper series, the 'schisto-calcareous' beds, made up of dolomites with chert bands. Their prevailing dip is away from the coast towards the central part of the Congo Basin. Passing inland, the lower beds, which are exposed in narrow strips around the schist boundaries, are everywhere followed by the overlying dolomite series.

Around Mayembe the two series are represented by calcareous sandstones and cherty limestones respectively. Further south, between San Salvador and Bembe and from there to Kiballa, thick beds of arkose, quartzite, and calcareous sandstones are surmounted by dolomites and limestones.

The age of this system is doubtful. Micro-organisms have been found in the limestone of Mayembe, but they are so ill-preserved as to be indeterminable in sufficient detail to serve as an index of age. Further south, however, the system continues through Benguela and

[1] Pres. Ad. Brit. Assoc. Rep. for 1911, p. 370.
[2] Brogger, *Zeit. Kryst.*, xvi, p. 55, 1890.

Mossamedes to Damaraland, where a thin series of conglomerates and arkose beds is followed by the famous Otavi dolomites. *Orthoceras* has recently been found in the latter formation, and it is therefore certain that the dolomites are not older than the Silurian.[1] Barrat considered the Angola and French Congo equivalents to be of Devonian age, but the basis of his correlation is of doubtful value as it depends only on lithological comparison with the rocks of far distant areas. Subject to the same criticism is Studt's correlation of the Otavi dolomites with the Dolomite series of the Transvaal system and the dolomitic beds of the Cango Series.

Important copper deposits are found in the Bembi dolomites and limestones, occurring in the same way as those of the Otavi dolomites, and of the still more valuable Katanga (Kambove) dolomites. All these dolomites are probably of Silurian age, but the copper ores are not altogether confined to this horizon, as they occur also in the schists of Angola and in the Cenomanian calcareous grits and conglomerates of Senza do Itombe.

Karroo (?) *Formation.*—In the basin of the Quanza River, around Dondo, a coal-bearing formation has been known for many years. It rests unconformably on the Palæozoic limestone and on the Archæan complex, and dips gently towards the south-west. The lower beds contain oil-shales and a thick seam of coal, and are followed by grey grits and conglomerates, above which lies a much coarser conglomerate which is characterized by a chocolate or reddish tint. Similar grey and red grits, but without the coal-bearing formation, are found on the Palæozoic rocks of the French Congo. It seems probable, from their lithological characters and position in the sequence, that the carbonaceous rocks of Angola are of Lower Karroo age. They are certainly post-Silurian and pre-Cretaceous.

Cretaceous and Tertiary.—The Cretaceous beds of Senza do Itombo lie unconformably on the Karroo and the Archæan, and dip to the south-west. Elsewhere Cretaceous rocks unconformably underlie the Tertiary deposits of the coastal belt, but they are recorded only in vague terms, and their distribution cannot yet be laid down on a map. The Tertiary limestones and sandstones extend along the coastal belt uninterruptedly, except for a doubtful break south of Ambriz, where their outcrop narrows down to a mile or two. Both Eocene and Miocene fossils have been collected, but the distribution of the two types, and the possibility of an unconformity between them remain to be worked out. Alluvial deposits and lateritic sands and gravels form a widespread blanket along the coastal belt, adding a further obstacle to the inherent difficulty of mapping in a tropical country.

Tertiary Igneous Rocks.—Between Senza do Itombo and Bango an interesting series of alkaline igneous rocks was discovered by Colonel Andrade. They are apparently intrusive into both Karroo and Cretaceous formations, and in common with the similar igneous rocks of the Kamerun and Adamaua, they are most probably of Tertiary age. Lava-flows, associated with plutonic and minor intrusions, are all represented in this igneous suite, which includes nepheline phonolites

[1] Studt, p. 91, 1912.

and syenite, with olivine monchiquite and ulrichite containing the brown hornblende, barkevikite.

Summary.—The geological succession in North-Western Angola is as follows, rocks of doubtful position being placed on the right:—

	RECENT DEPOSITS.	
TERTIARY	Miocene Eocene	Alkaline igneous rocks.
		Irruptive contact.
CRETACEOUS	Cenomanian.	
KARROO (?)	Red Conglomerate Grey Grits Carbonaceous Beds	Diabase Intrusions.
PALÆOZOIC	Dolomite and Limestone Series.	
SILURIAN (?)	Bembizi Beds.	
ARCHÆAN COMPLEX	Granulitic Albite Granites.	
		Irruptive contact.
	Gneisses and Gneissose Granites.	
		Irruptive contact.
	Schists and Crystalline Limestones.	

(To be continued in the June Number.)

REVIEWS.

MEMOIRS OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES. THE GEOLOGY OF THE COUNTRY AROUND WINDSOR AND CHERTSEY. By HENRY DEWEY, F.G.S., and C. E. N. BROMEHEAD, B.A., F.G.S. pp. i–vi, 1–123. 1915. Price 2*s.* 6*d.*

THIS memoir is an explanation of Sheet 269 of the 1 inch Geological Map. Pressure of work due to the War has, however, delayed the colour-printing of the map, and it is not yet ready for publication, but the authors give a sketch-map of the area on the scale of 4 miles to the inch. (p. 2.)

The sketch-map shows that the district is divided into three nearly equal parts: (1) mainly London Clay in the centre and west; (2) Bagshot Sand in the south; and (3) river gravels and brickearth on the north-eastern side of the area.

In the first of these parts the London Clay occupies a large tract, Windsor Park and much of Windsor Forest being upon it, and it also extends underground over almost all the rest of the district. Its thickness is about 400 feet in the east and rather less than 300 feet in the west. The Basement-bed with *Ditrupa* and shells is noted in several places and appears to be continuous. Fossils are not uncommon, and the authors give a list of considerable interest from near the top of the formation at Bracknell. There is a small exposure of Reading Beds in the north-western corner of the area, and they have been pierced in well-sections elsewhere. The thickness varies from about 100 feet in the south to 60 feet in the north. Chalk is found at the surface in the north-eastern corner of the district and also at Windsor Castle. In the old series of Geological Survey maps the Windsor Chalk is shown as part of the main mass of Chalk of the Chiltern Hills, but, as was suggested some time ago by Mr. Whitaker, it is now proved to be a small inlier due to a post-Eocene anticline. This is explained by the authors in a most interesting horizontal section (p. 13), which shows how the Chalk of the Castle Hill projects through the Eocene formations.

The second or southern third of the district is occupied by what used to be known as the Bagshot Sands. There has been some discussion as to whether they rest, conformably or unconformably, on the London Clay, and the authors find that in part of the district the junction is conformable with passage beds, whilst in the western part there is an abrupt change of sedimentation with indications of erosion of the London Clay before the Bagshot Sands were deposited The Bagshot Sands were divided by Prestwich in 1847 into three divisions, all of which can be more or less satisfactorily correlated with beds in the Hampshire Basin. The question thus arises whether to use the London Basin or the Hampshire Basin names, and the authors of the present work have decided to restrict the name Bagshot to the lowest of the three divisions, and to use the Hampshire names Bracklesham and Barton for the middle and upper divisions respectively. (p. 32.)

The Bagshot Beds are mainly current-bedded sands with thin layers of clay and pipe-clay and occasionally beds of pebbles. The thickness does not exceed 120 feet, and they thin to 20 feet towards the north. There are practically no fossils.

The Bracklesham Beds contain clay suitable for brick-making and beds of green sand. Fossils have been found which satisfactorily prove their Bracklesham age. The thickness is estimated at 100 feet at St. George's Hill, near Weybridge, and in the west of the district the thickness may be as much as 80 feet, but is very variable. (p. 42.) Pebble beds occur in places. Ironstone, an impure carbonate of iron, is found at the junction of the Bracklesham and Bagshot Beds, and was dug for smelting round St. George's Hill in the eighteenth and beginning of the nineteenth centuries. It is remarked that no other Tertiary iron-ore has been worked in the Thames Basin, though ore of about the same age was formerly worked at Hengistbury Head on the Hampshire coast. (p. 92.)

The Barton Beds consist of light-coloured quartzose sand with occasional beds of loam and clay and more rarely seams of pebbles. Bedding is seldom seen and current-bedding, so common in the Bagshot Beds, is exceptional in this upper series. The colour is usually yellow or buff. Very few fossils have been found in this district. This is the topmost Eocene bed in the area, and the full thickness is not preserved. The present thickness may slightly exceed 100 feet at Cæsar's Camp, Easthampstead. Greywethers or sarsen stones have been found in considerable abundance in the district, and though not seen in situ in Barton Beds, the authors think it probable that they may have been formed in them.

Much of the surface of this southern third of the district is covered by Plateau Gravel, and the authors remark that "Presuming that the gravels are the remnants of a once-continuous sheet, they appear to have been deposited in a fan on a sloping surface which conformed in its general outline to the present configuration of the Thames valley". (p. 59). Pieces of chert probably derived from the Lower Greensand of the high ground about Hindhead are common in these gravels.

The third, eastern and north-eastern, part of the district is covered by river gravel and brickearth. It comprises the whole area north of the Thames and small tracts to the south of that river and by the River Wey. The authors separate the gravels into three terraces—the 100 feet terrace or Boyn Hill Gravels, the 50 feet terrace or Taplow Gravels, and the lower terrace or Flood-plain Gravels—and they observe that these divisions appear to correspond with the sequence of types of flint implements. Thus the Boyn Gravels are characterized by implements of Chellean and Acheulian types, while that of Le Moustier first appears in the Taplow terrace, though this contains also occasional specimens of the older forms which are probably derivative. (p. 67.)

The river gravels younger than those of the Taplow terrace are included in the Flood-plain gravels. There was a considerable area of brickearth mainly resting on gravels belonging to the Taplow terrace, but it has been largely removed for brick-making. The authors describe the Alluvium and peat, and give an interesting list of land and freshwater shells from a section near Old Windsor.

In an Appendix a considerable number of wells and borings are recorded. The Palæozoic floor has not been reached in the district, the Lower Greensand being the oldest formation touched. This is not surprising, as the base of the Gault is here at a great depth more than 1,000 feet below Ordnance datum in the tract to the south of Slough, as will be seen on reference to the maps by Dr. Strahan in his Presidential Address to the Geological Society for 1913.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

March 24, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President announced the Award of the Proceeds of the Daniel-Pidgeon Fund for 1915 to Mr. E. Talbot Paris, B.Sc., who proposes to continue his researches on the Lamellibranchia of the Rhætic, Lias, and Lower Oolites of England.

The following communication was read:—

"The Stratigraphy and Petrology of the Lower Eocene Deposits of the North-Eastern Part of the London Basin." By Percy George Hamnall Boswell, B.Sc., F.G.S.

The following divisions of the Lower Eocene occur in the area:—

London Clay—Basement-bed only.
The Pebble Beds and accompanying sands.
Reading Beds.
Thanet Beds.

The unconformity of the Eocene upon the Chalk is discussed, and reasons are given for regarding the layer of green-coated flints at the bottom of the Thanet Beds in the area as a true basal conglomerate. The Eocene deposits overstep the Chalk zones from the zone of *Ostrea lunata* to that of *Micraster cor-anguinum*, and also transgress the Chalk surface-contours; owing to the greater dip of the base of the Eocene, the latter also bevels off the zone in South-Eastern Suffolk.

Evidence is adduced to show that the London Clay overlaps the Lower London Tertiaries, and rests directly upon the Chalk in Norfolk. The Reading Beds also overlap the Thanet Beds in the western part of the area. A hypsometrical map of the Chalk surface in the London Basin is presented, and a minimum estimate of the unconformity, in terms of thickness of Chalk removed, is given for the northern part of the Basin.

Isopachytes for the London Clay and Lower London Tertiaries (the north-western feather-edge of each deposit being the zero isopachyte) have been plotted, and since the beds thicken on each side of a central area in South-Eastern Suffolk, where the sub-Eocene Chalk surface gradient is least, the curves are seen to be convex to a central axis. The Chalk zones, Chalk surface contours, Lower London Tertiaries, and London Clay successively change strike as they are traced north-eastwards. The instability over the axis, which may be of Charnian trend, took the form of an earth-ripple forced north-eastwards, throughout Eocene times, towards that part of East Anglia where the Palæozoic platform rises. The unconformity of the Pliocene deposits upon the Eocene and the Chalk is shown to be significant in this connexion.

Stratigraphical details of the various divisions and descriptions of new sections are given. Tables of mechanical analysis (obtained by elutriation) throw light on the conditions of disposition, and permit of the adoption of an exact terminology. The visible Thanet Beds are of two facies: (*a*) the Ipswich or Eastern type, with predominant green clays, and (*b*) the Sudbury or Western type, characterized by the prevalence of light-coloured sands.

The variations in lithology of the Reading Beds are described, and it is shown that the Pebble beds belong lithologically and petrologically to the Reading Beds, but that their scanty fauna is a London Clay one. The fauna of the London Clay is also enumerated, and the author is of the opinion that the bed was deposited under isostatic conditions accompanying a sagging on each side of the central axis mentioned above.

The distribution of the sarsens in the area is plotted out on a map, and their petrology is considered; it is concluded that, in this district, they are derived from the sands of the Reading Beds.

The mineral constitution of the various divisions of the Eocene beds is discussed in detail. The mineral assemblage is seen to conform to one type throughout (characterized by occasional small, angular, colourless garnets, also by abundant staurolite, tourmaline, and kyanite), but differences occur which allow of the beds being easily distinguished one from the other. There is remarkable constancy in mineral composition over wide areas, and in deposits lithologically different. The mineral suite of the succeeding Pliocene beds (with abundant red garnets, andalusite, mica, and ferromagnesian minerals) is shown to be very different, and the constituents of various other East Anglian deposits are also compared.

In the Thanet Beds, ferromagnesian minerals are present and undecomposed, the micas being rare. In the shallow waters in which the Reading Beds were deposited, the biotite, hornblende, pyroxene, and epidote appear to have been largely lost, aided no doubt by current-drift along a shore. The Pebble beds show occasionally natural concentration of heavy minerals by oscillatory current-action. In the subsidence which followed when the London Clay was deposited, muscovite and biotite appeared in fair quantity, and hornblende became abundant. Such minerals as magnetite, ilmenite, rutile, zircon, glauconite, etc., are plentiful throughout.

II.—Mineralogical Society.

March 16, 1915.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Professor G. Cesàro: Orpiment from Balia, Asia Minor. Results of a crystallographic examination were given.—Professor G. Cesàro: Stereographic projection of a cone touching the sphere of projection along a small circle.—Dr. S. Kôzu: The dispersion of adularia from St. Gothard, felspar from Madagascar, and moonstone from Ceylon. A second communication giving the results of careful measurements. —Dr. G. T. Prior: The Meteoric Stone of Launton, Oxfordshire. The stone, which was seen to fall on February 15, 1830, was acquired by Dr. Lee and placed in his natural history collection at Hartwell House, near Aylesbury. After his death it was, through confusion with another meteorite, lost sight of until 1895, when it was found by Dr. Fletcher wrongly labelled in the Lee Collection, and was secured for the British Museum. The stone belongs to the white-veined chondrite group, and in chemical and mineral composition agrees with other members of that group.

III.—The Geological Society of Glasgow.

At a meeting of the Geological Society of Glasgow, April 8, 1915, Mr. Duncan Smith exhibited hazel-nuts and wood found in March, 1914, when preparing foundations for the restoration of Paisley Abbey. The occurrence was investigated by the Rev. C. A. Hall and Mr. Smith, who found that the nuts were in great abundance, mostly in pockets in a gravel about 11 feet from the surface. Consideration of the evidence led to the conclusion that the nuts and other vegetable matter associated with them had been accumulated at the time of the 25 foot beach.

Dr. David Ellis read a paper on "Fossil Moulds and Fossil Bacteria". He outlined briefly the characteristics of the living representatives of the two groups of organisms referred to, and said that it was about eighty years since fungi had been recognized in the fossil state and several species had already been named. The subject had received attention from Worthington Smith, Felix, Williamson, and Renault.

Being particularly interested in the iron bacteria it had occurred to him to examine a series of microscopic sections of Mesozoic ironstones with the object of discovering whether they contained any evidences of the existence of members of that group at the period of formation. He had not succeeded in tracing iron bacteria in these rocks, but had found the remains of moulds which had possessed a similar power to deposit iron oxide on their membranes. The delicate hyphæ were found ramifying through fragments of organic matter, showing reproductive organs and branching portions. He found the evidence so definite that he felt justified in naming the organisms, but not in relating them to modern species. He had found these organisms in the ironstones of Lincolnshire and of Raasay. In examining a thin section of a nodule from the Gault, near Folkestone, he had detected the presence of bacteria, represented by both bacilli and cocci, whose size and characteristic appearance left no room for doubt as to their identity. The paper was illustrated by a fine series of microphotographs.

In reply to points raised in the discussion by Professor Gregory, Mr. Tyrrell, and others, Dr. Ellis said that he did not think there was a possibility of his having been misled by deceptive appearances. He could not suggest how such delicate organisms had been preserved, but the fact remained that they were there in the rocks.

IV.—Liverpool Geological Society.

April 13, 1915.—W. A. Whitehead, Esq., B.Sc., President, in the Chair.

The following paper was read: "The Mineralogical and Chemical Constitution of the Triassic Rocks of Wirral." Part II. By H. W. Greenwood and C. B. Travis.

While confirming and extending the results recorded in the first part of the paper (Proc. Liverpool Geol. Soc., vol. xi, p. 116) the authors had established some very significant facts, the full discussion of which they postponed, pending further investigation. They were satisfied, however, that, contrary to the prevalent view, secondary silica played a negligible part as a true cementing material of the rocks, the most important agents in this respect being the carbonates of lime and magnesia. These were normal constituents of the Wirral Trias, and not due to secondary infiltration. Analyses of the Keuper Marls also invariably showed a high content of lime. Barytes was widely distributed throughout the rocks, and was not a surface manifestation.

On the whole the authors were led to the conclusion that the ingredients of the sandstones were derived ultimately from rocks of a granitoid character, but as regards the Upper Bunter and Lower Keuper, although the constituents were alike in both cases, their mode of occurrence seemed to indicate that the former had been derived from earlier formed sediments, and the latter directly from the erosion of an igneous area.

CORRESPONDENCE.

ZONES OF THE CHALK AREA OF NORTH-WEST MIDDLESEX AND EAST BUCKS.

Sir,—For some time up to about two years ago I was occupied, when occasion permitted, in zoning the Chalk area of North-West Middlesex and East Bucks. Latterly I have been too busy, and I find the chance of my ever being able to take up the work again very remote. I am therefore sending you a note of such results as were obtained.

The sections most carefully worked were—

(1) About 1 mile N.W. of Denham, in the most southerly Chalk outcrop.
(2) About 1 mile N. of Denham, just under the h 5 in the 1 in. drift sheet.
(3) Troy Mills, about 2 miles N of (2).
(4) Harefield Cement Works Pit.
(5) Harefield Gelatinous White Co.'s Pit.
(6) Springwell Pit.
(7) Pit on Golf Course at Sandy Lodge.

Marsupites and *Uintacrinus* were nowhere found, in spite of careful search. From Nos. 1 and 2 came several high-zonal *M. cor-anguinum*, and from Nos. 3, 4, and 7 low-zonal *cor-anguinum*. In Nos. 5 and 6, both of which have a section of about 80 feet from the pit floor to the top, the floor in each case being nearly at the same level above O.D., both *M. cor-anguinum* and *M. cor-testudinarium* were found, as well as passage forms, so that both these zones would seem to occur. *M. cor-testudinarium* was also found in an excavation below the level of the floor at Harefield. The junction of the zones can be conveniently taken at a band of comminuted mollusca and echinoids which occurs in both sections.

This band was only a few feet above the floor at Harefield, but at Springwell it was about half-way up, or nearly 40 feet above the floor. This gives a difference of 30 feet in a north–south distance of 1½ miles, or 20 feet to the mile. As *M. cor-anguinum* was found near Chorley Wood, nearly two miles north of Springwell, and the same species occurs near Watford, there must be a rather sharp flexure of the Chalk south of Rickmansworth, bringing up the lower zones.

Fossils are not common. except in the lower parts of pits 5 and 6, i.e. in the *M. cor-testudinarium* zone. Most characteristic are a flat broad-based pentangular variety of *Discoidea cylindrica* and *Echinocorys vulgaris*. *Parasmilia centralis* was not infrequent. The flints are very spongiferous.

Chas. E. P. Brooks.

"Homeleigh," 3 Roseleigh Avenue,
Highbury, N.

OBITUARY.

RICHARD LYDEKKER,

B.A. (Camb.), F.R.S., F.G.S., F.Z.S., J.P. Herts.

Born 1849. Died April 16, 1915.

It is with deep regret we have to record the death at Harpenden, in his 66th year, of our esteemed friend Richard Lydekker. He was for many years a fellow-worker in palæontology with your Editor, in the British Museum (Natural History), where by his scientific labours he has left his mark on the Zoological and Geological Collections in both Departments.

Born in 1849, Richard was the eldest son of the late G. W. Lydekker. He entered Trinity College, Cambridge, 1869, where he passed second in 1st class Natural Science Tripos in 1871, taking his B.A. degree. He joined the staff of the Geological Survey of India in 1874, and during his residence there as an officer of the Survey spent much time in the field, and we have to thank him, amongst other excellent pieces of geological work, for a detailed account of the vast mountainous area comprised within the territories of Kashmir.

He commenced his labours in the domain of Vertebrate Palæontology, by a study of the Siwalik fossils, and was able to contribute numerous valuable additions to the classic work of Falconer and Cautley. Many other Tertiary Vertebrata, from various parts of India and Burma, have been examined and described by him. He has also given an account of the Pleistocene fauna of the Karnul caves, and has contributed to our knowledge of the Indian Mesozoic Reptilia. He returned to England in 1882, and took up his residence permanently at his family home, Harpenden Lodge, Harpenden, Herts. In the same year Mr. Lydekker married Lucy Marianne, the eldest daughter of the Rev. Canon O. W. Davys, M.A., Rector of Wheathampstead.

Shortly after this he commenced to study and catalogue the Fossil Vertebrata in the Geological Department of the British Museum (Natural History), and in 1884 completed vol. i of a series of five volumes on *The Fossil Mammalia in the British Museum*, the fifth volume being issued in 1887. From the Mammals he proceeded to the Fossil Reptilia and Amphibia, the catalogue of which was published in four volumes between June, 1888, and April, 1890. The final volume, on the Fossil Birds, he brought out in 1891, thus earning for himself with the Museum staff the good-natured sobriquet of "our lightning cataloguer". Indeed, Mr. Lydekker at that time was undoubtedly the most assiduous worker, as a scientific man, I think, that I ever met, and his catalogues of the vast collections of fossil vertebrates in the Museum are pioneer works of the greatest possible value to his successors.

With Professor H. A. Nicholson, Lydekker undertook a third and much enlarged edition of the former's well-known textbook of Palæontology, in two massive volumes, the second, on the Vertebrata, being by him. With Sir William Flower he collaborated in an excellent volume on *Mammals, Living and Extinct*, which appeared in 1891 (pp. 764). Later, on the recommendation of Flower, he visited the National Museum of Argentina at Buenos Aires, and there prepared and published, with the help of Dr. Moreno, the Director, "Descriptions of South American Fossil Animals" (for the Annals Museo La Plata). He assisted Sir William Flower in the rearrangement of the entire mammalian collections (after Dr. Günther's retirement) in the Zoological Galleries of the British Museum (Nat. Hist.), and continued similar work almost up to the time of his death. In 1896 he produced a volume entitled *The Geographical History of Mammals*, to which he attached especial importance, and of which he always hoped to publish a revised edition. His work in the laborious task of preparing the part of the *Zoological Record* relating to the Mammalia from the year 1887 on is of the greatest value to workers on that group, and enabled him to acquire an unrivalled knowledge of the literature referring to it.

His contributions to the GEOLOGICAL MAGAZINE exceed seventy in number (1883–1901), whilst his papers to the Geological and Zoological Societies, to the *Annals and Magazine of Natural History*, and to other publications were equally numerous; but latterly, as he himself said, in 1902[1]: "I have lately been led to transfer my time and attention more and more to *recent animals* and to geographical distribution; and much of it has been given also to popular or semi-popular writing, rather than to strictly scientific work."

Nevertheless, Lydekker's latter publications have been of a highly interesting and instructive character, as for example his work on *The Deer of All Lands*; *Wild Oxen, Sheep, and Goats of All Lands*; *The Great and Small Game of India, Burma, and Tibet*; *The Great and Small Game of Europe, North and West Asia, and America*; three volumes of Allen's Naturalists' Library, mostly Mammals; *Horns and Hoofs*; *The Game Animals of Africa*; *The Sportsman's British Birds*; *A Trip to Pilawin*. Mr. Lydekker is also the author of the part of the *Royal Natural History* which relates to the Vertebrata, a work well illustrated, not a mere compilation, but full of original matter of great value, largely drawn from the author's own knowledge.

The last important work in which Lydekker was engaged was a *Catalogue of the Ungulate Mammals in the British Museum.* Of this three volumes have appeared, in the two last of which the author was assisted by Mr. Gilbert Blaine: the completion of the fourth volume occupied the last days of his life, and he succeeded in leaving it ready for the press.

The rapidity with which he worked did not always allow Lydekker to do himself full justice, but, when the vast mass of his output is considered, it will be recognized that he has done far more to advance the knowledge of the living and extinct Vertebrates than is usually accomplished by those whose energies are crippled by the fear of making mistake. No man was ever more ready to place his knowledge at the disposal of others, and many of the younger generation of workers in his field will gratefully remember his help.

In 1883 Mr. Lydekker joined the Geological Society, and was a member of Council for some sixteen years and served as a Vice-President. He was elected a Fellow of the Royal Society in 1894. He received the award of the Wollaston Fund from the Geological Society in 1891, and the Lyell Medal in 1902.

He leaves two sons, Lieut. Gerard O. Lydekker and Lieut. Cyril R. Lydekker, and three daughters.

In addition to the members of his family many scientific men attended the funeral, which took place at Harpenden on April 20. Mr. C. E. Fagan, Dr. S. F. Harmer, Mr. Ogilvie Grant, Mr. J. G. Dollman, Mr. W. P. Pycraft, Dr. C. W. Andrews, Mr. H. Jenkins, Mr. W. G. Chubb, represented the British Museum (Natural History); Mr. Hugh Barclay, the Norwich Museum; and a large and representative body of Naturalists and friends.

[1] Anniversary Geol. Soc. Lond., February 21, 1902.

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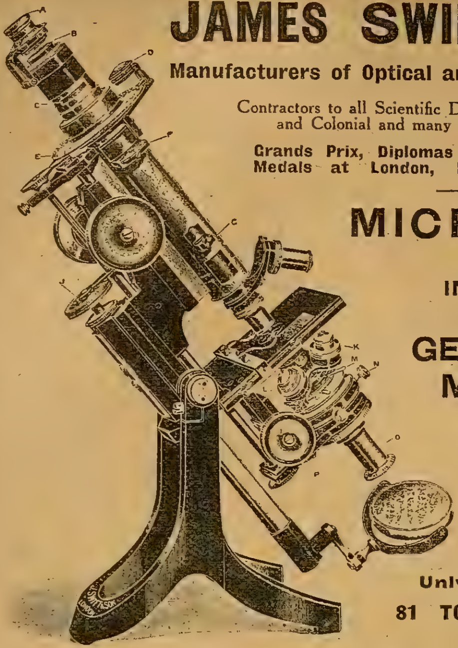

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NEW SERIES. DECADE VI. VOL. II.

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ORIGINAL ARTICLES.

I.—The Solway Basin and its Permo-Triassic Sequence.

By J. W. Gregory, D.Sc., F.R.S.

THE Solway Firth is the only important ria on the western coast of Scotland; it has a complex history, for denudation and earth-movements of several different dates have contributed to its formation. Uncertainty as to the essential structure of the Solway valley at present renders doubtful its position in the valley system of Southern Scotland. The Solway–Carlisle basin is generally represented as occupying a synclinal between the Lower Palæozoic hills of the Lake District and of the Southern Uplands of Scotland. Thus the sections by E. W. Binney (1865, p. 369, ref. p. 249) and Mr. T. V. Holmes (1889, p. 247, and 1899, pp. 22, 40) represent the valley of the Solway and its eastern continuation as lying along a synclinal and resting on a great thickness of Triassic rocks. The axis of the synclinal is marked by the Lias which occurs to the west of Carlisle. The Solway–Carlisle basin cannot, however, have such a simple synclinal structure, for Carboniferous rocks occur at the surface near the northern shore of the Eastern Solway. This fact is shown by a boring for coal made in 1794 in an old quarry beside the Kirtle Water at Redkirk Mill, 1½ miles to the south-west of Gretna Green. The bore journal was published in Singer's Agricultural Survey of the County of Dumfries, 1812, pp. 670–3; and as that book is scarce and the bore important the record may be conveniently reprinted.

Journal of Boring for Coal at Redkirk, in the Parish of Graitney, 15th May, 1794.

	yds.	ft.	in.		yds.	ft.	in.
White stone	4	2	0	Strong white stone with water			6
Gray beds		1	0	Stone calm		1	4
White stone	2	0	0	Gray beds		2	3
White metal partings			6	Hard brown randed with white		2	6
Brown stone	1	1	6	Light brown stone		2	4
Bleas [1] stone		2	0				
Stone calm [2]	2	0	0	*Carried forward*	14	0	11

[1] *Blaes* or *blaise* = shale; *bleas* is doubtless a misprint.

[2] 'Calm' is defined by J. Barrowman in *A Glossary of Scotch Mining Terms*, 1886, p. 15, as 'White or light coloured blaes'.

	yds.	ft.	in.
Brought forward	14	0	11
White metal[1] partings			5
Brown stone		2	8
Hard white stone			9
White metal partings		1	0
Stone calm	1	0	8
Stone calm		1	0
Gray whin with water, large		1	7
White metal partings			4
Strong white stone	2	1	0
White metal partings			6
White stone with water, large	1	0	0
White metal partings			2
Soft white stone		2	10
White metal partings			3
Stone calm		1	0
White stone	4	0	6
Brown metal partings		1	0
Brown stones	5	0	0
Gray beds			4
Gray freestone with water		1	7
Gray stone with water	1	1	2
Brown metal partings			6
Brown stone	1	1	0
Strong brown stone	1	2	6
Hard blae stone		1	5
Strong white stone with water	1	1	8
Blae stone	1	0	7
Hard white stone, thin beds		1	0
Strong blae stone	1	2	10
Soft blae stone			8
Red calm		1	0
Strong brown stone	1	0	7
Strong brown stone	3	0	9
Gray stone		2	10
Brown metal partings			3
Strong brown stone	2	0	6
White stone, hard		1	7
Hard white stone			9
Strong gray randed[2] stone		2	5
White stone			4
Brown metal partings			4
Brown randed stone with white		1	3
Strong coal-pipe			1
Brown randed calm			6
Light brown randed stone	1	0	6
Light brown randed with white		1	10
Strong white stone	1	1	9
Blaes metal partings			1
White stone		1	0
Brown stone calm		1	0
Gray beds		2	0
Brown stone calm			5
Gray		3	9
Hard white stone with water			11
Strong gray beds		2	2
Hard white stone		1	4
White scap metal			5
Gray beds, strong		1	6
Strong white stone		1	0
Strong gray beds		1	11
Strong gray beds		2	0
Blue metal partings			6
Strong brown stone		1	0
Gray beds		2	0
Hard brown stone	1	1	4
Dark brown calm		1	11
White stone			2
Blue metal			6
Hard blaes stone	1	0	0
Blue metal partings			6
Strong white stone		2	9
Strong white stone, with coal-pipes	1	2	9
Strong blaes stone			9
Hard blaes stone		1	3
Blue metal partings			2
Dark-brown calm stone			7
Dark calm mixed with white		2	0
Dark bleas stone		2	0
Strong gray bed	1	0	0
Hard white stone	1	1	9
Hard gray stone		1	6
White stone		2	4
Strong bleas stone		2	0
Light-red metal			2
Soft blue calm stone			6
White stone mixed with coal-pipes		1	1
White stone			7
White stone, strong		1	8
Light-brown stone		1	11
Light-brown stone		2	8
Hard brown stone		2	6
White stone	1	0	0
Dark-brown stone calm	2	0	6
Hard brown stone		2	2
Strong gray beds with water	1	0	9
Red calm stone	1	0	0
Fath. 45	1	2	10

This succession with its 108 beds in 275 feet, the abundance of white stone, gray whins, "strong gray beds," and layers with coal, indicates that this bore passed from the surface through the Lower

[1] 'Metal' is defined by Barrowman (ibid., p. 44) as 'Hard rock; whin'. In this journal it doubtless meant shale, according to its use in Cumberland and Northumberland (Wright, *English Dialect Dictionary*).

[2] 'Randed' may mean 'striped' or may be a misprint for 'banded'.

Carboniferous Series. The whole succession of the beds in the bore is quite unlike the local Permian or Trias.

This bore journal is not the only evidence for the existence of the Lower Carboniferous beds at this locality; for, as the Busbys remark in an appendix in Singer (1812, p. 673), the grey sandstones may be seen on the bed of the Kirtle Water near the site of the bore. These beds outcrop at the distance of about 450 yards down-stream from the bore and are 250 yards below a footbridge near Old Gretna. They occur at the point represented on the six inch map (Dumfriesshire, Sh. 64 N.W., ed. 1898) beside the 'a' of Kirtle Water, five hundred yards west of Old Gretna. The microscopic character of these sandstones agrees with those of the Lower Carboniferous Series, and they differ from those of the adjacent Triassic beds.

It is clear that Carboniferous rocks occur near the northern shore of the Eastern Solway as well as along the Western Solway. Hence the southern as well as the northern[1] margin of the Annan Sandstone, the Dumfriesshire continuation of the St. Bees Sandstone, rests unconformably on the Carboniferous without any Permian beds intervening.

Whether the Carboniferous rocks of Redkirk are bounded to the south by a fault or pass beneath an unconformable cover of Permian beds is uncertain. The probability appears in favour of their southern margin being faulted. The Solway district is traversed by three series of faults; the dominant faults trend from east to west or from east-north-east to west-south-west; and they are met by two other sets of faults; one set trends from north and south or from north-north-west to south-south-east, and the other set trends from north-west to south-east. The Redkirk bore is close beside the line of continuation of the Boltonfell fault, one of the pair of ridge faults by which, 8 miles to the east of Redkirk, the Lower Carboniferous rocks are upfaulted between the Trias on the south and the Coal-measures at Riddings.

The presence of a raised platform of Carboniferous rocks to the north of the Solway, on which the Bunter Sandstones were deposited directly, shows that whether the Carboniferous beds are cut off to the south by a fault or are covered by the Permians, the Solway basin had been initiated by subsidences and faulting in pre-Bunter times; while it was enlarged by post-Triassic faulting.

The outcrop of Carboniferous rocks at Redkirk is therefore opposed to the synclinal theory of the Solway, according to which, moreover, the St. Bees Sandstone extends under the Solway and continues beneath North-Western Cumberland deep below a thick sheet of gypseous shales. The existence of this extension of the St. Bees Sandstone rests on slender grounds which appear untenable. The evidence of the Redkirk bore has an important bearing on the classification of the Permian and Triassic systems in this district as well as on the structure of the Solway valley. Sir Archibald Geikie, in his preface to the Geological Survey memoir on the neighbourhood of Carlisle, remarked that the classification of the rocks advocated by Mr. T. V. Holmes in the memoir differs from that which was adopted

[1] See Peach & Horne, 1903, pl. iii, sects. 4, 5.

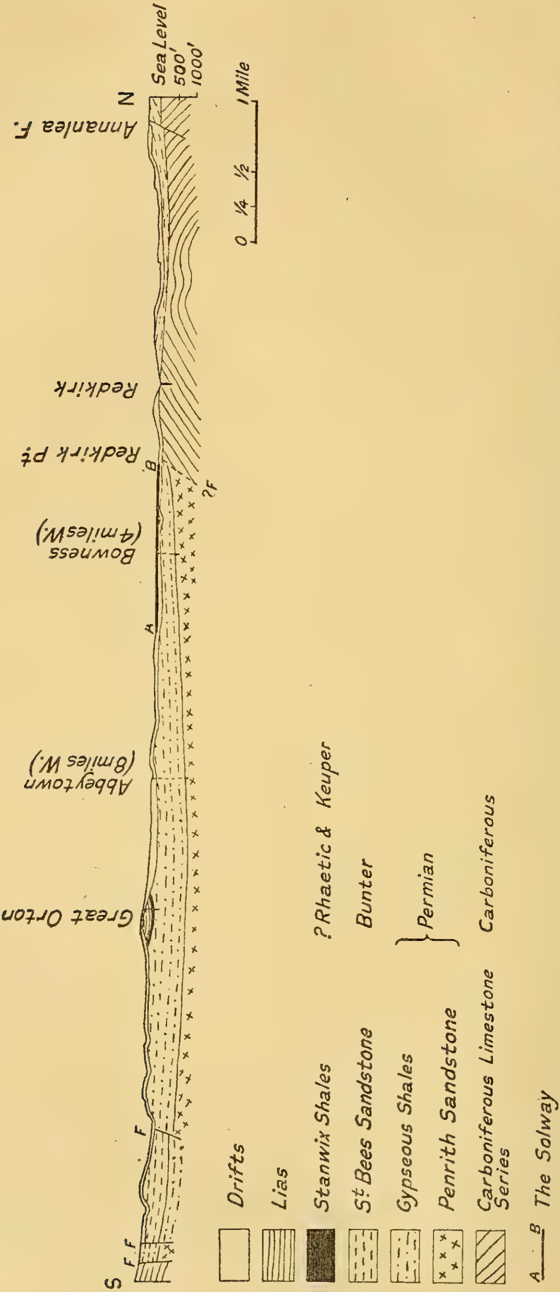

FIG. 1.—Section across the Solway Firth (A–B) and the Carlisle Basin, from the Annanlea Fault in the St. Bees Sandstone of Dumfriesshire to the Carboniferous Series south-west of Carlisle.

by Aveline, Sir Andrew Ramsay, and the Survey maps. Mr. Holmes' classification has been most generally followed.[1] The difference between them may be shown by the following table :—

	Carlisle Memoir and Holmes' paper of 1889.	Geological Survey Maps.		Age now generally accepted.
TRIAS	Stanwix Shales	Stanwix Shales (include Upper Gypseous Shales of Holmes)	Keuper	? Rhætic[2]
	Kirklinton Sandstone	Kirklinton Sandstone		Keuper
PERMIAN	Upper Gypseous Shales	—		—
	St. Bees Sandstone	St. Bees Sandstone	Bunter	Bunter
	Lower Gypseous Shales	Gypseous Shales	Permian	Permian
	Penrith Sandstone	Penrith Sandstone		

The essential difference is that according to Mr. Holmes there are three series of shales, viz. the Stanwix Shales above and two lower series containing gypsum; and of these Gypseous Shales he placed one above and the other below the St. Bees Sandstone. The Geological Survey maps recognize only two beds of shales, for they represent the Stanwix Shales as the same horizon as Mr. Holmes' Upper Gypseous Shales. Aveline—in order to avoid an unconformity at the base of the Lias, while accepting the beds at the bottom of the Bowness and Abbeytown bores as the St. Bees Sandstone—identified the Stanwix Marls as the continuation east of Carlisle of the Gypseous Shales of the Great Orton, Bowness, and Abbeytown bores; and against this view Mr. Holmes indignantly and justly protested (1889, pp. 244–7). Etheridge plausibly suggested (in Holmes, 1881, p. 298) that the Stanwix Marls might represent the tea-green marls of the Rhætic; otherwise the Rhætic beds would be absent from this district.

Mr. Holmes admits that only one bed of Gypseous Shales has been seen on the surface; but he holds that the bores at Bowness and Abbeytown revealed the existence of a thick series of Gypseous Shales above the St. Bees Sandstone.

The Bowness bore (Holmes, 1899, pp. 54–5) was sunk in 1809 ; it passed through 322 feet of Gypseous Shales and left off in a "red stone". No one living appears to have seen this material, which Mr. Holmes has identified as the St. Bees Sandstone. The bore at Abbeytown was put down in 1875–6 ; it went through 198½ feet of alluvium and glacial deposits; then through 746½ feet of Gypseous Shales; and passed for 75 feet through sandstones which Mr. Holmes has identified as the St. Bees Sandstone (1899, p. 54). As

[1] e.g. by H. B. Woodward, *Geology of England and Wales*, 2nd ed., 1887, p. 212 ; also J. E. Marr, in *Geology in the Field*, Geol. Assoc. 1910, p. 655.

[2] The Stanwix Shales may include some Upper Keuper as well as the Rhætic, for Holmes (1889, p. 242) claims an unconformity between these beds and the Kirklinton Sandstone.

this identification is responsible for the difficulty in the interpretation of the geology of the Solway–Carlisle basin, its careful reconsideration is justifiable.

If Mr. Holmes' identification of the rock from the Abbeytown and Bowness bores be correct, there would be a double series of Gypseous Shales, one above and one below the St. Bees Sandstone. The existence of the Lower Gypseous Shales is undoubted; they separate the St. Bees Sandstone from the Penrith Sandstone. The Geological Survey maps express some hesitation as to whether this series should be included in the Permian or the Trias, but they show it as certainly situated between the St. Bees and the Penrith Sandstones.

The claim for the existence of the Upper Gypseous Shales rests upon the identification of the sandstone at the bottom of the Bowness and Abbeytown bores as the St. Bees Sandstones. It may appear most unlikely that such an expert in the geology of North-Western Cumberland as Mr. Holmes could be mistaken in this determination; and his view has been further recommended by the improbability of the conclusion offered as the alternative, namely, that the Stanwix Shales are the eastern continuation of the Gypseous Shales of the Great Orton and Bowness bores. Nevertheless, several considerations suggest that the sandstone at the base of the Abbeytown and Bowness bores is really the Penrith Sandstone.

1. Though the two formations are usually easily distinguished, mistakes are possible, as some layers of the St. Bees Sandstone contain redeposited Permian material; most of the sandstone in question was clearly not typical St. Bees Sandstone.

Mr. P. Fleming Smith, the Manager of the Vivian's Boring and Exploration Co., Ltd., the present title of the firm which, as the Cumberland Diamond Boring Co., put down the bore in 1875–6, tells me that the report-book of the bore shows that few cores were obtained from the last 200 or 300 feet and *none from the lowest beds*. The report-book is supported by the testimony of one of the charge men on the staff of the Company who worked at the boring. He states that the lowest bed "of soft sandstone made no core". Hence any identification of the rocks at the bottom of the bore must have been based on fragmentary material.[1] The debris of the St. Bees Sandstone and Penrith Sandstone might easily be mistaken; and under those circumstances the determination of the material at the lower end of the bore as St. Bees Sandstone cannot carry weight against the general stratigraphical evidence.

2. Mr. Holmes was probably predisposed by his classification of the Red Rock Series of Cumberland to regard these sandstones as the St. Bees Sandstone, for he made this identification also for the sandstone of the Bowness bore, of which the only description is "red stone".

[1] In the Carlisle Memoir, issued 1899 (p. 20), the identification of the soft red sandstone as the St. Bees Sandstone is advanced on the examination by Mr. Holmes and his late colleague R. Russell of "the cores showing this lowest bed". As no cores were obtained from that bed if the identification were based on cores, they must have come from some upper part of the boring or from another locality.

3. The rocks at the base of the Abbeytown bore are reported by Mr. Holmes as follows (1899, p. 54):—

	Thickness.		Depth.	
	ft.	in.	ft.	in.
Grey sandstone and blue sandy shale .	24	6	969	6
Soft grey sandstone	12	6	982	0
Soft red and white sandstone . . .	6	0	988	0
Soft red sandstone (left off in) . . .	32	0	1020	0

Mr. Fleming Smith has kindly sent me a copy of the journal of the lowest 100 feet of the bore. It is as follows:—

ft.	in.	ft.	in.	
8	0	902	0	Red and blue shale, with gypsum and sandstone beds.
11	0	913	0	Red and grey shale, with gypsum and sandstone beds.
13	0	926	0	Red and grey shale.
1	0	927	0	Blue shale.
	6	927	6	Grey sandstone.
5	0	932	6	Red and blue sandy shale.
	6	933	0	Dark grey sandstone.
3	0	936	0	Blue shale.
1	6	937	6	Grey sandstone.
3	6	941	0	Red sandy shale.
3	0	944	0	Blue sandy shale.
1	0	945	0	Red and grey sandy shale.
15	6	960	6	Grey grit.
21	6	982	0	Grey grit (soft; no core).
6	0	988	0	Red and white sandstone, soft.
37	0	1025	0	Red sandstone, soft (no core).

This description of the lowest beds appears suggestive of the Penrith rather than of the St. Bees Sandstone.[1] The most characteristic feature of the St. Bees Sandstone is that it consists of posts of sandstone separated by layers and partings of shale; the Penrith Sandstone, on the other hand, contains no such shales and usually consists of thick beds of soft sandstone, the colour of which is more variable than that of the St. Bees Sandstone. The lowest 65 feet of the bore was through red, white, and grey sandstone; this composition and the absence of interbedded shale agree better with the upper part of the Penrith Sandstone than with the St. Bees Sandstone.

4. Mr. Holmes describes the lowest bed of the Abbeytown bore as the ordinary St. Bees Sandstone; but he lays stress on the correlation of the overlying grey sandstone with that exposed on the bank of the Caldew, 240 yards north of the dyke near Dalston. This position would place that cliff almost up to the fault which in Mr. Holmes' map (1881, pl. xi) separates the St. Bees Sandstone from the Kirklinton Sandstone; and if the grey sandstone be included in the Kirklinton Sandstone, as Mr. Holmes' map shows to be quite possible, then it would belong to a formation which Mr. Holmes (1899, pp. 6, 31) describes as resembling the Penrith Sandstone and not the St. Bees Sandstone.

[1] The descriptions in the bore journal might conceivably refer to the Upper Coal-measure Sandstones of the Whitehaven type. But even the waste of these measures would be easily distinguished from the Permian and Triassic Sandstones. The lowest beds are probably later than Carboniferous. There is, however, no improbability in the gypseous shales resting unconformably on the Carboniferous in this district.

5. Another improbability involved by the acceptance of the Upper Gypseous Shales is the conclusion that in addition to a minor unconformity between the Stanwix Shales and the Kirklinton Sandstone (Holmes, 1889, p. 242) there is a very marked unconformity at the base of the Lias. Mr. Holmes' section (1899, p. 41) shows the Lias transgressing from the Gypseous Shales over the Kirklinton Sandstone on to the Stanwix Shales. This unconformity is based mainly on a boring made at Great Orton in 1781. According to the record quoted by Mr. Holmes (1899, p. 22) this bore "found a blue stone 3 fathoms from the surface—continued with different stone, mostly bluish till 38 fathoms, then changed to red stone or clay sometimes mixed with veins of white till they came to 60 fathoms". Mr. Holmes interprets this record as showing that the Lias extended from 3 to 38 fathoms, and that the bore then entered the Upper Gypseous Shales and kept in them to the bottom of the bore at 60 fathoms. H. B. Woodward, on the other hand, in a passage in his memoir on the Lias quoted by Mr. Holmes (1899, p. 38), considered that the upper 210 feet of "different stone, mostly bluish" included some Rhætic beds, and this conclusion would appear to be most probable. The recorded "veins of white", instead of being veins of gypsum, the probable explanation, might possibly be based on thin beds of white or grey sandstone; and if so the lower beds might be either Stanwix Shales or Kirklinton Sandstone. But Mr. Holmes' conclusion that the beds containing these white veins are of gypsum is probably correct, as Gypseous Shales may be expected beneath a thin layer of Upper Keuper near Great Orton. The unconformity represented by Mr. Holmes in the Carlisle Memoir at the base of the Lias is possible; but the persistent conformity of the Lower Lias, Rhætic, and Upper Keuper is so widespread throughout Britain, that it requires stronger evidence than the meagre description of the Great Orton bore to establish a strong unconformity between the Lower Lias and the Keuper.

6. The abandonment of the assumed upper series of Gypseous Shales would remove the main difficulty in the interpretation of the Carlisle district, viz. the assumption that west of Carlisle there is above the St. Bees Sandstone a bed of Gypseous Shale which is several hundreds of feet in thickness, and of which there is not a trace along the outcrop of the St. Bees Sandstone, east of Carlisle; although to the south-east of the city there is a thick bed of similar Gypseous Shale, below the St. Bees Sandstone.

7. The Redkirk bore shows that the Permian beds at Bowness should be nearer the surface than was expected when the Annan Sandstones were regarded as the northern part of a sheet of St. Bees Sandstone which extended in a simple synclinal under the whole Solway–Carlisle basin.

The Redkirk bore further shows that the St. Bees Sandstone north of the Solway rests unconformably on the Carboniferous; and south of the Solway, to the west of Carlisle, the most northern certain extension of the St. Bees Sandstone is in the band which passes 3 miles south of Carlisle, and continues through Dalston and Wigton to the coast at Allonby Bay. This band probably lies in a trough fault.

There is no evidence apart from the identification from the two bores of the presence of St. Bees Sandstone in Cumberland anywhere to the north of that band; and the probabilities seem to me in favour of its absence. On the north of the Solway the St. Bees Sandstone extends as far west as Annan; but the Redkirk bore shows that the only known beds on the southern side of that area of St. Bees Sandstone are Lower Carboniferous Sandstone. There is no trace of the St. Bees Sandstone to the west of Annan; the rocks of the Penrith Sandstone group reach the northern shore of the Solway at Caerlave rock; and south of the coast of Dumfries in this area a band of Carboniferous rocks, covered by sea and drifts, probably connects the Carboniferous outcrop at Arbigland with that of Ruthwell. These Carboniferous rocks may be covered to the south by Penrith Sandstone or by the Gypseous Shales, and the natural rock to find beneath the Gypseous Shales at Bowness and Abbeytown is the Penrith Sandstone.

As the St. Bees Sandstone does not occur north of the Solway further west than Annan, there is no improbability in that formation not extending as far west as Bowness or Abbeytown on the southern side. The assumption of a sheet of St. Bees Sandstone under North-Western Cumberland, north of the Wigton–Allonby outcrop, appears to me improbable.

Summary of Conclusions.

The occurrence, as shown by the Redkirk bore, of the Carboniferous rocks near the surface on the northern shore of the eastern Solway, and the identification of the red rocks at the bottom of the Abbeytown bore as Penrith Sandstone, render unnecessary either the assumption of the existence of the Upper Gypseous Shales or the view that the Stanwix Shales are the continuation of the Gypseous Shales of the Abbeytown and Bowness bores. Thereby is removed the chief difficulty in the interpretation of the geology of North-Western Cumberland and the Solway Firth.

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II.—The Petrology of the Suffolk Box-stones (Crag).

By P. G. H. Boswell, D.I.C., B.Sc.

(PLATE X.)

ALTHOUGH much has been written upon the palæontology of the Suffolk box-stones, no description appears hitherto to have been published of the petrology of these boulders. This is the more curious on account of the light it might throw upon the disputed question of their source, no similar sandstone having yet been recognized with certainty in situ.[1] The most recent account of the molluscan fauna is by my friend Mr. Alfred Bell. In a preliminary paper[2] he has given a list of sixty-three species (excluding cetacean bones, teeth, crustaceans, etc.), about twelve new species and varieties being described. Mr. Bell has now kindly let me see in advance the MS. of a revised list of Mollusca (seventy-six species), much new box-stone material having been obtained in the last few years. As a result of recent work, he considers the affinities of the fauna to be rather with the Rupelian (Continental Oligocene) than with the Bolderian or Diestian, as he formerly thought. Mr. Clement Reid, in *The Pliocene Deposits of Britain* (Mem. Geol. Survey, 1890), considered the box-stones to be of about the same age as the Diestian Beds, but Mr. F. W. Harmer has, in later publications, been inclined to consider them to be rather older and of very early Pliocene age.

The box-stones are masses of a fairly hard brown sandstone, about the size of the fist, or a little larger. These boulders are often well rolled, but sometimes occur as flattened tabular lumps, and have received their name from workmen owing to the fact that about 10 per cent of them, on being broken open, are found to have enclosed fossil remains. Fragments of wood and bone, as well as teeth and casts of Mollusca, occur in this way, and, while it appears to be probable that some of the box-stones may have been formed by concretionary segregation of iron-oxides and calcium phosphate and carbonate around organic nuclei, others appear merely to be the broken-up fragments of a ferruginous sandstone. The latter may have been derived from iron-impregnated bands in the original sandy beds like those met with in the Lower Greensand or Red Crag.

Large muscovite flakes glisten here and there, but macroscopically the sandstone cannot be said to be highly micaceous, nor very compact. Casts and impressions of shells are sometimes seen, and more rarely a fragment of a calcite shell, e.g. *Pecten*. As in the Coralline and Red Crags when they are decalcified, the aragonite shells have usually disappeared as a result of solution.

Appearance in thin section.—A number of box-stones from Foxhall, Sutton, Waldringfield, the mouth of the Deben, and also from the collection of the Imperial College of Science and Technology have been sliced and examined. The numbers in square brackets, attached

[1] Lyell drew attention to the similarity between the box-stones and some Antwerp beds near Berchem (Q.J.G.S., vol. xxvi, p. 513, 1870). Other authors have noted their similarity to the Diestian.

[2] "On the Zones of the East Anglian Crags": Journ. Ipswich and District Field Club, vol. iii, p. 5, 1911.

to descriptions, etc., refer to the slides and accompanying mineral separations in the collection preserved at the College.

Under the microscope the rock is seen to be a coarse sandstone made up largely of grains of clear quartz set in a brown matrix, often so dark in colour as to appear isotropic, but occasionally showing aggregate polarization. There is little uniformity in the size of the grains, the smaller helping to fill up the interstices between the larger, but occasionally there are patches of the brown cement, free from grains, as big as the largest of the latter (Fig. 1). The average

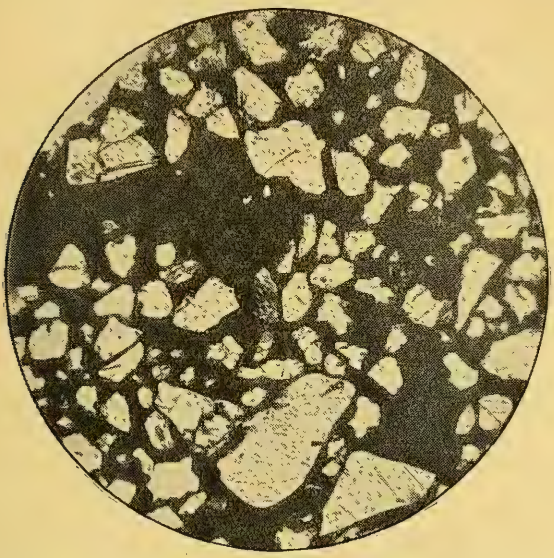

FIG. 1.—Box-stone, Pettistree Hall, Sutton [204], showing large angular quartz-grains and a high proportion of phosphatic matrix.

diameter of the fragments is about ·3 mm., the smallest being about ·12 mm., and the largest up to ·5 mm., or even 1 mm., diameter. There is very little material above the last size. The larger grains of quartz are somewhat rounded, and those of felspar almost square, but the smaller grains are subangular to angular, the tendency to rounding diminishing with the size. Some of the smaller grains are astonishingly sharp and angular, most being rather triangular, but a few being of long and irregular, quadrilateral form. Usually there is an entire absence of any grading in size. A specimen from Sutton [206] differs in containing smaller grains, averaging ·16 mm. diameter, set more closely together, with much less matrix (Fig. 2).

The quartz is usually very clear and colourless, and free from enclosures. In a few cases, however, parallel rows occur of very small inclusions, like those met with in quartz from granites and gneisses, and rarely mineral inclusions (zircon, etc., but no sillimanite) have been seen. Some grains are coated with limonitic dust, and occasionally there is a thin border of subsequently deposited quartz separated from the original grain by a very thin pellicle of brown material. Cracks sometimes occur and are stained brown. Undulose extinction (strain-shadows), characteristic of quartz from crystalline rocks which have undergone dynamic metamorphism, has been observed, but is not common; one compound grain of quartzite set in the brown matrix was made up of three or four closely locking grains of quartz, one of which showed strain-shadows.

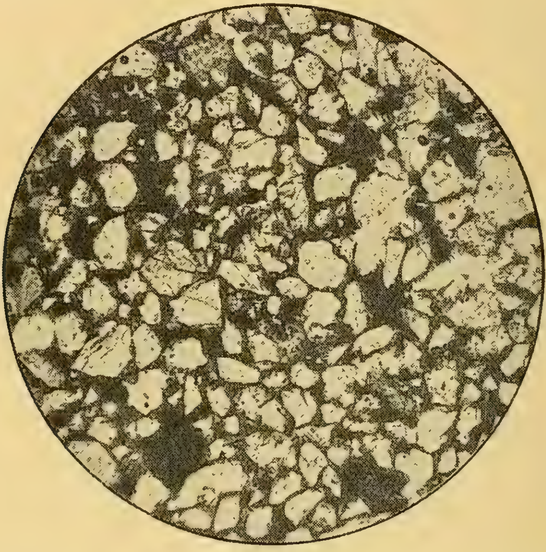

FIG. 2.—Box-stone, Sutton. [206.] Extreme variety with very little cement.

In thin sections little felspar is to be seen, the proportion of the grains of felspar to quartz being about one to fifty. Some of the larger grains are almost square, and the mineral is generally full of alteration products; twinning is usually not seen.

As a general rule, casts only of the Mollusca are found in box-stones, so that it is interesting to meet occasionally cross-sections of shell-fragments, apparently of bivalves. These sections are long, and somewhat lenticular, having a strong brown-stained border, and an interior made up of an aggregate of small yellow-stained recrystallized calcite grains.

The deep colour of the matrix seems to mask effectually the heavier minerals which are found on crushing and separating (see pp. 254–7). Certain patches exhibiting aggregate polarization occur here and there, but are too deeply stained to be determinable. Ovoid and circular dark-brown isotropic pellets, probably representing some organic remains, are occasionally seen, but no structure can be made out in them, and the round empty hollows sometimes found may be due to their removal.

The brown matrix is often present in considerable amount, measurements of relative volumes of sand-grains and cement-filled interspaces being for extreme values—sand 19·8 per cent, matrix 80·2 per cent, and sand 80·1 per cent, matrix 19·9 per cent. (These values were calculated from the areal distribution in thin sections, e.g. Figs. 1 and 2.) An analysis of material from the mouth of the Deben [203] gave the following proportions by weight: sand 57·43 per cent, matrix 42 57 per cent, from which the proportions by volume, sand 62 per cent, and matrix 38 per cent, can be calculated roughly on the assumption that the sand is quartz and the matrix calcium phosphate.

The cement sometimes exhibits concentric banding due to growth round the quartz-grains. On treatment with dilute acid a large proportion of phosphate is found,[1] and an analysis of the rock kindly carried out by my colleague, Mr. G. E. Kirby, A.R.C.Sc., B.Sc., shows 20·1 per cent of calcium phosphate, 6·5 per cent of calcium carbonate, and 0·84 per cent of soluble silica.

This percentage of phosphate is far too great to be accounted for by the little detrital apatite present, hence it probably exists in the cement as limonite-stained phosphorite. Glauconite may also have played a part in cementation, but it has not been detected as such. Surprisingly few grains of this mineral occur in the residues. Limonite itself undoubtedly acts as a cement, and prolonged boiling with acid is required to clean the crushed sandstone. Cementation has also been effected by the deposition of secondary silica, partly as quartz and partly in an opaline form. The latter appears to be soluble in acid, and is found on analysis of the matrix; the finding of opal also among the detrital mineral grains suggests that some of the apparently isotropic pellets and matrix may be this form of silica obscured by iron-staining. Other pellets may be iron-stained calcareous material. Marked effervescence with cold dilute acids indicates that calcium carbonate also is present as cement.

Mineral constitution.—The sandstones, being fairly hard, were crushed in a steel mortar, and, after sifting to 1 mm. the compound grains were removed. The material was subjected to prolonged boiling with dilute hydrochloric acid to remove the matrix from the grains. A clean, white, micaceous sand was obtained, but it is noteworthy that the muscovite is not strikingly apparent in the untreated box-stones. The sand was then treated with either bromoform or Sonstadt solution (mercuric potassium iodide), and crops obtained of density $< 2{\cdot}59$, which contained potash felspars, opal, etc., between 2·59 and 2·8, which contained quartz and plagioclase felspars, and $> 2{\cdot}8$. The last crop was then farther separated by electro-magnetic action (after minerals such as magnetite had been removed by means of a bar-magnet), and the non-magnetic portion treated with methylene iodide (density 3·33). The crop of density between 3·33 and 2·8 contained andalusite, apatite, mica, etc. Mineral grains were mounted temporarily in clove oil (R.I. 1·534), as being very similar in refractive index to Canada balsam, and in other oils of known and differing refractive indices, for examination

[1] There is sufficient in the rock for a fragment to yield the ordinary blowpipe reactions for a phosphate.

under the microscope in transmitted and reflected light. Individual mineral species were isolated by hand-picking under a lens ($\times$ 20 diameters) in which work a background of black paper was found to be advantageous. Besides the well-known opaque minerals, certain others can be recognized by their characteristic appearance in reflected light, and can be picked out with ease. Muscovite is easily separated by rolling the residue down a rough sheet of paper. Kyanite is clear and glassy, and usually more or less rectangular in form. Andalusite is whitish or dirty-white in appearance, the grains being more irregular. Garnet is pink to colourless, and its fracture causes the mineral to have a well-marked sugary look. Staurolite occurs as deep golden grains, sometimes brownish, but not so metallic-looking as rutile, and epidote as pretty lemon-yellow to yellow-green grains, both minerals being present as irregular fragments. Rutile has a characteristic reddish-brown metallic appearance, and is often prismatic. Green hornblende is easily recognized and isolated. Tourmaline has a smoky, bottle-green to brown tint, and frequently the larger grains have a hummocky shape.

The following is a brief account of the more important minerals:—

Magnetite is fairly abundant, either as angular fragments or in well-rounded grains about ·13 mm. in diameter. A few crystals with octahedron faces have been noted.

Garnet is an abundant and characteristic mineral, being usually pale pink, but occasionally reddish or colourless. In nearly every case the grains (·2 to ·4 mm. diameter) are very irregular and of all shapes, showing sub-conchoidal fracture and re-entrant angles, but a few occur as platy fragments due to the imperfect (110) cleavage. Rounded grains, if they occur, are rare, and all appear to be entirely isotropic. Inclusions, apparently glassy, occur as well-shaped dodecahedral negative crystals. (Pl. X, Fig. 1.)

Zircon is not so abundant as usual in sediments, in which it is ubiquitous. Small crystals less than ·12 mm. long are not common, the average size of the abraded prismatic grains being ·13 $\times$ ·03 mm. Good crystal form and angles are rarely seen.

Rutile is fairly plentiful, rounded prismatic grains of red-brown tint being common. The yellow variety is rarer, and well-formed crystals are scarce. The grains are larger and more numerous than those of its constant associate in sediments, zircon.

Ilmenite occurs in profusion, constituting a large part of the first electromagnetic crop. The fragments are usually small and rather angular (·13 mm. diameter), but a few are rounded. They are often surrounded by a comparatively clear border of leucoxene, showing aggregate polarization. By reflected light the mineral has a bright black lustre, and is sometimes striated, but grains are often coated, in part or entirely, with the whitish alteration product, leucoxene.

Tourmaline.—This mineral is usually of the kind varying from a greyish- to yellow-brown. A very pretty reddish-purple form also occurs. Rounded and broken grains, averaging ·18 mm. diameter, are common, but well-formed prismatic crystals are smaller and rarer; these sometimes exhibit hemimorphism, the prisms being terminated by rhombohedra.

Calcite occurs as grains recrystallized from shell-fragments, but has mostly been removed by solution.

Apatite is of rare occurrence, probably having been in part removed by solution. It is present as rounded grains which are almost isotropic, and yield a uniaxial figure, being optically negative. Such grains are caused by the imperfect (0001) cleavage. It also occurs in tiny well-formed prisms ($\cdot 1 \times \cdot 025$ mm.) often terminated by pyramids. These crystals have a clear, limpid appearance, fairly high refractive index, straight extinction, and very low birefringence.

Quartz is the most abundant constituent of the sandstone, the larger grains being moderately rounded, and the smaller, angular. The only inclusions observed have been parallel rows of tiny bubbles, which appear to be glassy and isotropic. The average dimensions are given on p. 251.

Andalusite is abundant in the box-stones and is characteristic of the assemblage. A quantity of it (Pl. X, Fig. 2) was isolated from the non-magnetic portion of the residue of density $> 2{\cdot}83$ and $< 3{\cdot}33$ by hand-picking, and the identification confirmed. The usual size of the grains is ·18 to ·35 mm. diameter, and most contain abundant dark, opaque, rounded inclusions. The grains are bounded by the good cleavage parallel to (110), and a few show pleochroism in a salmon-pink tint for light vibrating parallel to the X-axis, in the direction of which the grains are often elongated. The grains show straight extinction, low polarization colours, and a curved brush in convergent polarized light.

Staurolite is a characteristic and dominant mineral. It occurs as irregular grains, averaging ·23 mm. in diameter, varying in colour from a pale gold to yellow-brown. The fracture is very irregular, some fraying being seen at the edges, and the pleochroism, in tints of golden-yellow, is very marked. Inclusions are abundant, and appear to be glassy and of varied form. (Pl. X, Fig. 4.)

Topaz is rare, and is found as platy colourless grains not unlike mica, determined by the basal cleavage. The refractive index is, however, higher, the optical sign is positive, and the optic axial angle is greater. Topaz is met with in the non-magnetic portion of the residue of density $> 3{\cdot}3$.

Marcasite is not abundant and may be an authigenic constituent. It occurs in small ragged grains, with a yellowish-white metallic lustre by reflected light, but is partly altered to brown limonite.

Actinolite.—A number of fibrous, colourless elongated grains, with an extinction angle up to 8°, have been referred to this mineral.

Hornblende, green and pleochroic, with a low extinction angle, occurs frequently as grains determined by the perfect (110) cleavage.

Epidote is fairly abundant, occurring in yellow-green grains (averaging ·2 mm. diameter) which can be hand-picked by reflected light. It is found in the middle magnetic crop with staurolite and tourmaline. The grains are sometimes tabular on account of the basal cleavage, and somewhat rectangular, the imperfect cleavage parallel to (100) being occasionally seen. Many of the irregular grains are pleochroic in yellow-green tints, and show, in convergent light, the emergence of an optic axis. (Pl. X, Fig. 3.)

Muscovite is very plentiful in the heavy residues and is present as large flakes, most being rounded, ·5 mm. in diameter and ·02 mm. in thickness. On account of the large surface area and consequent slow settlement in heavy liquids, much muscovite remains with the light crop of density $< 2·8$.

Sphene (?).—Some irregular coffee-brown grains of high refractive index are doubtfully referred to this mineral.

Orthoclase is fairly plentiful, but is much less abundant than plagioclase. The crystal fragments are often roughly rectangular and are generally much kaolinized.

FIG. 3.—Kyanite grains from box-stone, Sutton. [206.] (*a*) Large bent grains. (*b*) Some of the smaller grains in Fig. 3*a*.

Microcline is not abundant, but grains have been observed with albite-twinning (symmetrical extinction angle 16°) and refractive index below 1·525.

Kyanite is abundant, but in some samples a little less so than andalusite. Many of the grains are of considerable size, and a few of the largest are bent in a remarkable manner. Most of the grains are tabular, lying upon the perfect cleavage faces parallel to (100). The (010) cleavage produces long grains, and the basal parting results in approximate rectangularity and cross-cracks. Pleochroism, in ultramarine blue, is very rare, but examples have been seen with a beautiful colour. The trace of the optic axial plane lies at about 31° to the edge (010) $\wedge$ (100), and plates lying on (100) give an emergence of the acute bisectrix. A few grains resting upon the (010) face have been observed, and these give straight extinction and no figure in convergent light. The average size of the crystals is ·44 mm., but some large crystals are as much as 1·7 mm. in length. The latter are sometimes bent in a curious way, and from their extinction it is concluded that the irregularity is due to crystallization along the bent foliation planes of metamorphic rocks. (Text-figs. 3*a*, *b*.)

Plagioclase is fairly plentiful, and from its specific gravity and mean refractive index appears mostly to be oligoclase-andesine, but rarely a few grains occur of refractive index greater than 1·560. These are probably labradorite.

Glauconite.—A very few grains only of this mineral have been observed in a large number of samples examined, and the rarity of its occurrence is in sharp contrast to its abundance in the Diestian of Belgium and Coralline Crag of East Anglia. It may be, as in the case of the Antwerp Crag and the Red Crag of Suffolk, etc., that decomposition of the glauconite has taken place, resulting in the production of the limonite and secondary silica which are so abundant in the rock. There is no justification for applying the term 'glauconitic sandstone' to the box-stones, as several authors have done. Nevertheless, the association of phosphatic minerals and glauconite is to be expected on genetic grounds.[1]

Limonite is very abundant, giving the sandstone its brown or yellow colour. It coats quartz grains and impregnates the matrix, probably occurring as a cement. Grains which appear by reflected light to be limonite, but which occur in the middle-magnetic crops (limonite is truly non-magnetic) are no doubt actually magnetite, glauconite, or other iron-bearing minerals which have undergone surface decomposition.

Opal.—A mineral which often coats other grains (magnetite, etc.) and occurs also in the sand of density below 2·59 is seen to be clear or pale brownish by transmitted light, but white and milky by reflected light. Its refractive index is below that of Canada balsam (1·532), and it appears to be isotropic, so has been referred to opal. It probably acts in part as a cement.

It is evident from the foregoing list that the box-stones have a peculiarly rich and characteristic mineral assemblage. On comparing the list with the assemblages of other deposits, particularly, perhaps, the various divisions of the East Anglian Tertiaries, we can say that the Box-stone Bed is characterized by the large size of its detrital grains, and its richness, both as regards variety and occurrence, in heavy minerals. The typical minerals are red garnet, andalusite, staurolite, epidote, muscovite, and kyanite, with, less importantly, green amphiboles, brown tourmaline, etc. Rutile and zircon appear to be ubiquitous in deposits of all ages, but are really less abundant than usual (especially zircon) in the box-stones. It is rather surprising not to meet with more biotite, particularly as this mineral occurs, though not abundantly, in the Thanet Beds and London Clay in East Anglia, and is plentiful in the later Crag deposits. Opal, limonite, phosphorite, and glauconite are probably authigenic, and marcasite and some of the leucoxene may be also of subsequent formation.

The mineral assemblage detailed above indicates very clearly that the source of the box-stones is to be looked for in an area adjacent to a massif of crystalline rocks which have undergone regional metamorphism, and bear quartz with strain-shadows, felspars, and such minerals of metamorphic origin as tourmaline, andalusite,

[1] J. J. H. Teall, Proc. Geol. Assoc., vol. xvi, p. 383, 1900.

staurolite, epidote, muscovite, and kyanite, in great abundance. The richness of the mineral suite and the angularity and large size of the grains, with the absence of grading in size, suggests that the constituents had not travelled far. The extraordinary profusion of andalusite and muscovite is noteworthy, but it is not clear why biotite should be as rare as it is, when epidote and other ferromagnesian minerals are plentiful and fresh.

The nearest area which would yield the detrital minerals described is undoubtedly the region of the Ardennes, the metamorphic rocks of which have been described in detail in so many publications of the Belgian geological societies. In this connexion the mineral constitution of the Tertiary deposits of Belgium and Northern France is interesting. A discussion of these, and a comparison of the minerals of the Box-stone Bed with those of the East Anglian Eocene, Pliocene, and Glacial beds, must be reserved for a future paper.

A comparison of the petrology of the box-stones with that of British Pliocene deposits generally is also interesting. In mineral constitution the box-stones have no counterpart, so far as the writer's examination of sediments goes. The Lenham Beds (as well as other high-level ferruginous sandstones of the North Downs), which have been said to possess a molluscan fauna similar to that of the box-stones, show interesting petrological differences. Writing in 1870 on the box-stones, Sir E. Ray Lankester gave it as his opinion that they were very probably of the same age as the Lenham Sandstone, which they resembled most closely in condition and contents.[1] In the light of more recent work the statements require modification. The fauna is an older one, and the beds differ petrologically. The material of the Lenham Beds is finer, less angular, and is well graded. There seems to be no phosphatic cement. The mineral assemblage is less rich than that of the box-stones, and garnets, if present, are rare. (The same remarks apply to the Netley Heath sand.) While the box-stones and Lenham Beds may have been derived from the same area, the former certainly did not arise from the denudation of the latter. Neither is there any striking resemblance between the box-stones and such Diestian material as the writer has been able to obtain from the Continent, although the mineral composition of the latter beds is similar but less rich. More work remains to be done upon the Continental Tertiary deposits.

The mineral suite of the box-stones conforms generally to that of the East Anglian Pliocene deposits, and is entirely different from the assemblage found in the Eocene beds. It is highly improbable that the same tract of country and area of rocks yielded the material of both series of sediments. The break in mineral composition between the London Clay or the latest Eocene deposits in East Anglia, the Bagshot Beds, and the box-stones, is as striking and significant as the palæontological gap.

My thanks are due to my friends Mr. Alfred Bell and Mr. S. A. Notcutt, of Ipswich, for providing me with some of the box-stone material examined.

[1] "Contributions to a knowledge of the Newer Tertiaries of Suffolk and their Fauna": Q.J.G.S., vol. xxvi, p. 501, 1870.

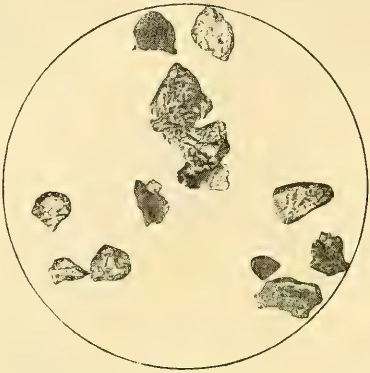

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Microphotographs of Grains of Heavy DETRITAL MINERALS from the Suffolk Box-stones.

PLATE X.

MICROPHOTOGRAPHS OF GRAINS OF HEAVY DETRITAL MINERALS FROM THE SUFFOLK BOX-STONES.

FIG. 1. Angular grains of pink garnet. Mouth of R. Deben. [203.] See p. 254.
,, 2. Andalusite, Sutton [206], many grains dusky with inclusions. See p. 255.
,, 3. Epidote, Sutton. [206.] The darker grains in the photograph are those giving the strong yellow-green tint due to pleochroism. See p. 255.
,, 4. Staurolite, Foxhall. [202.] Irregular angular grains, a few showing frayed edges. See p. 255.

III.—STUDIES IN EDRIOASTEROIDEA, VII. MORPHOLOGY AND BIONOMICS OF THE EDRIOASTERIDAE.[1]

By F. A. BATHER, M.A., D.Sc., F.R.S.

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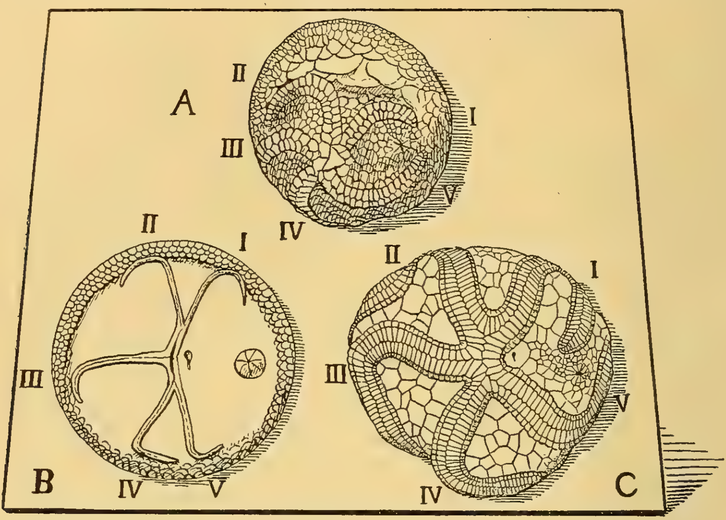
THE facts concerning the Curvature of the Subvective Grooves have been summarized in Study IV (1914, p. 122). They show that no distinction can be drawn in this respect between Edrioasteroidea and Cystidea Diploporita, as some have pretended.

The facts of individual growth, as inferred from a comparison of large and small specimens of the same species, indicate that the rays increased in relative length with age, and thus wound more and more along the periphery. It may further be inferred, from tracing the course of each ray, that the initiation of the curve was due simply to the primitively straight course of the ray being turned aside by the peripheral limit. It follows from this that the right-handedness or left-handedness of the coil was not a feature of the young, and that the one is not a mere reversal or mirror-image of the other. The distinction, however, being characteristic of species separated by other characters, cannot be fortuitous. There must have been some structure or habit in each species predisposing a turn of the coil in a solar or contrasolar direction. It is clear that the cause cannot have been, as Jaekel seems to suggest (1899, p. 24), a torsion of the circumoral region, for in that event the proximal and distal curvatures of a single groove would never be opposed, as they so often are, and that not only in the right posterior ray.

If the difference of coil were due to such a fundamental change in the constitution of the animal as would produce a mirror-image, then the change would be accompanied by a change in the coil of the gut from solar to contrasolar or *vice versa*. This, however, does not seem to have been the case, for such evidence as we have as to the position of the rectum indicates a solar coil (as viewed from the oral pole) whether the grooves were solar as in *E. buchianus* (Study II, 1900, p. 199) or contrasolar as in *E. bigsbyi* (Study IV, 1914, p. 167). Jaekel's conclusion that the gut of the Edrioasteroidea had the normal solar coil of Echinoderma is probably correct, though his main argument, drawn from the supposed constant contrasolar curve of the rays, rests on an incorrect premiss.

[1] Continued from p. 215.

A contrasolar curve of the rays, though not constant, is certainly prevalent in the Edrioasteroidea as a whole, and is regarded by Dr. A. F. Foerste (1914) "as the primitive condition among species with curved rays". Any explanation must, however, take into account the fact that it is so generally accompanied by a solar curve of the right posterior ray (V). To explain the latter feature, Dr. Foerste has put forward some plausible speculations, which if provided with a more extensive foundation of observed facts, might go far to solve the whole problem.



TEXT-FIGURE 1.—Diagrams to show the effect of a sloping position on the course of the rays.

A. A specimen of *Agelacrinus pileus*, traced from a photograph published by A. F. Foerste, 1914, op. cit., pl. ii, fig. 1. × 2 diam.

B. A diagram showing the effect of gravity on rays still marked by triradiate symmetry.

C. *Edrioaster bigsbyi* placed in the same position as A and B. Nat. size.

From observations mainly on *Agelacrinus pileus*, Dr. Foerste shows that the theca is frequently sagged to one side, and from this he infers the direction of slope of the surface (e.g. a valve of the brachiopod *Rafinesquina*) to which the Edrioasteroid was attached. If his argument be correct, then it appears that the right interradius (V IV) was generally directed upwards, so that the anus was to the right of the mouth. Assuming, as is natural, that the slope of the brachiopod valve was toward the direction of the prevailing currents, then the anal stream would be swept away without passing over either the mouth or any considerable part of the food-grooves; moreover the greatest width of the peristome would be in the line of the current. So far, then, the interpretation of the facts is consistent with a healthy pelmatozoic mode of life. (Text-fig. 1, A.)

Dr. Foerste applies this probable position of the living animal to account for the reversed, i.e. solar, curve of the right posterior ray (V). Speaking of an Agelacrinid with its fixed border of small plates, he writes (p. 404): "the position . . . would tend to increase the tension along the upper part of the margin and just within the adjacent part of the peripheral ring. If, at the same time, the anus were dragged slightly downward and toward the left, the proximal part of the right ray (No. 4) being directed up the supporting slope, then the greatest tension would be on the upper, right-hand side of the inner curve of the peripheral ring, possibly sufficiently below the distal part of the right posterior ray (No. 5), in young specimens, to loosen the contact between this part of the peripheral ring and the immediately adjacent part of the posterior or anal interambulacral area, and thus to admit of the curvature of the right posterior ray in a solar, rather than a contrasolar direction." He finds support for this view in the frequent presence of small plates "along the upper margin of the anal pyramid", the animal being oriented as above described. However that may be, the presence of such small plates on the solar side of the anus (as already recorded in *Edrioaster bigsbyi*, 1914, Pl. X, Fig. 9), certainly indicates the presence of the underlying rectum, and thus confirms the view that the gut had a solar coil.

Dr. Foerste's argument has been given in his own words because it is not easy to follow. If, however, he is correct as to the normal position of the living animal, then we might find herein a very simple explanation not merely of the solar curve of ray V, but of the contrasolar curve of all the other rays. If the animal be laid on a slope with the anus to the right of the mouth, then its various parts are all subject to a gravitational force pulling down the slope (text-fig. 1, B). The grooves, with their cover-plates, their heavy floor-plates, and the various systems of organs associated therewith, are heavier, i.e. subject to a stronger pull, than are the intervening thinly plated areas. Consequently, when the grooves have grown out so far that they have to turn one way or the other, they will naturally turn in the direction of this pull. In other words, grooves IV, III, and II will acquire a contrasolar bend, and groove V a solar bend. Groove I should, on this hypothesis, most naturally have a solar bend; but owing to the greater width of the posterior interradius and the primitive triradiate plan of branching, the proximal position of this groove may very well have been directed almost straight down the slope, so that the action of gravity would be indifferent, and its course might rather be determined by the encroachment of groove II. The strong re-curvature of groove V is further aided by gravity acting on the rectum; but in forms that had structures such as ampullae on the inner side of the floor-plates, the posterior mesentery would have opposed an effective bar to the passage of the groove across it.

This hypothesis is suggested by facts observed in undoubtedly sessile forms, and if it is to be applied to the Edrioasteridae, we must suppose that they also assumed a similar sloping habit. Here, as in so many similar cases, the field collector and observers have not supplied the laboratory worker with the desired evidence. The section across a specimen of *Edrioaster bigsbyi* (1914, Plate X, Fig. 10) shows that, in that individual at least, the right side was higher than the left. Let us, at any rate, test the hypothesis by applying it to the truly remarkable disposition of the grooves in that specimen (text-fig. 1, c). No sooner do we place the specimen on a slope, with the proximal region of ray IV directed upwards, than all the hitherto inexplicable curves appear the most obvious result of the downward pull. That peculiar inward bend of ray IV is a simple downward sag where its course is at right angles to the pull. The initial solar curves of rays III and IV, and the initial contrasolar curve of ray V, are similar sags, and contrast with the greater straightness of the corresponding region in rays I and II. Contrast again the sharp flexure of ray III, with the more rounded curve of ray II, and the still more open curve of ray I. At all points we see the action of the same force; a force which may be slight but which is always at work. Now at last we appreciate the true meaning of what was previously styled the "peculiar aspect of independent life" given to these rays by their varying curves. There is here a struggle between two forces: the internal tendency of the grooves to grow straight outwards from the mouth at equal distances from one another, and the external pull of gravity, acting equally on all the grooves, but affecting each in a different way according to its position. Thus arises that unlikeness in likeness which gives the fossil its peculiar beauty.

If there be any truth in this explanation, it will of course be necessary to suppose that other species, with rays otherwise disposed, lived in a different position. In *Agelacrinus hamiltonensis*, for instance, ray IV must have lain more to the right, and so have come under the pull of gravity on that side with the result that rays I, II, III have a contrasolar bend, and rays IV and V a solar bend. In that species, with no internal ampullae, groove V has come right round the anus. It is not quite so easy to explain those forms in which all the grooves are either solar or contrasolar, but in the former it is worth noting that ray V is not strongly bent in towards the anus (see *E. buchianus*, 1900, Pl. VIII, and *E. levis*, 1914, Pl. XII); it would appear from this that the pull of gravity was, at any rate, not being exerted in the same direction as in *E. bigsbyi*. The greater width of interradius I–II in *E. buchianus* also suggests that its position was uppermost, so that the anus lay to the left of the mouth instead of to the right. In genera and species of later date, whether the flexure be solar or contrasolar, we must not expect to find such direct traces of mechanical causes. Those forms, we may most naturally presume, repeat the direction impressed on their ancestors when the conditions of life may have been different; they themselves may emphasize the direction by additional growth, as in the long lash-like grooves of *Dinocystis*, but they are not likely to change it.

Whatever truth there may be in the hypotheses here erected on the suggestive fact of position first recorded by Dr. Foerste, it does at least seem clear that all the differences may very well be due to simple mechanical causes acting on the growing animal. There is no need to invoke any sudden change of structure or constitution, any shuffling of chronosomes, or any reversal of development in early stages, as, for instance, by the splitting of the fertilized ovum into dextral and sinistral halves. None the less, behind the simple mechanical explanation there still obtrudes the question: Why did one species place itself on a slope with its right side highest, and another species with some other side highest? Or if the external force was not gravity but the constant impact of a current, the question merely has to be posed in another form. There must be an answer to these questions, but we shall not discover it till we know the predecessors of these species, and perhaps not even then.

The Feeding of the Edrioasteroidea, as that of all other Pelmatozoa, was no doubt accomplished by the subvective system of ciliated grooves; but it does not follow that ciliary currents were the only means by which food was transported to the mouth. Reasons have been given for supposing that pores passed from the groove, between the floor-plates, to the thecal cavity in *Dinocystis* (1898, p. 545), in *Edrioaster buchianus* (1900, p. 196), in *E. bigsbyi* (1914, p. 124), and in *Steganoblastus* (1914, p. 198); and it has been argued, from the close similarity of the skeletal structures to those of an Asteroid, that there were external podia connected with internal ampullae. It is not supposed that these podia were provided with suckers, and without them they could not hand morsels of food along the grooves, or even assist the process in the way described by Dr. H. S. Jennings for *Asterias forreri* (1907, Pub. Univ. California, Zool., vol. iv, p. 93). They could, however, have performed some sweeping or pushing action, and may thus have contributed to the supply of food.

Respiration, it is probable, was the primary function of these podia. There is no sign of pores for papulae in any part of the thecal wall, so that these would have been the only extensions of thin-walled cavities available for the interchange of gases. The presence of a distinct hydropore confirms the view that the water-vascular system in these genera carried on some function of importance, whereas in Agelacrinidae the apparent absence of a hydropore is correlated with the absence of pores between the floor-plates.

The view that active podia existed in *Edrioaster* and its like, to which certain facts of structure point, is opposed by other facts of structure, namely, the completeness with which the cover-plates could close down over the grooves, and the position of the pores close up to the hinge-line of the cover-plates. The latter fact led Mr. W. K. Spencer (1904, p. 45) to cast doubt on the existence of podia, and to suppose that the pores had "a respiratory function", which means, apparently, that water was driven through them, by ciliary action (?), into some endothecal cavities not precisely indicated. Pores were supposed by him to be correlated with "firm skeletons", and to be absent from forms with "imbricating plates", which would "present large surfaces of membrane to the surrounding sea-water". This view, however, does not agree with the known facts; besides, the objection is not insuperable. Of course the cover-plates of *Edrioaster* were not closed when the animal was feeding, and it has already been suggested that they might open obliquely so as more readily to allow the podia to pass out between them (1914, p. 162). In the same place attention was directed to the possible openings immediately above the peripodium in *Edrioaster bigsbyi* effected by accessory cover-plates. Were it not for these accessory plates (1914, p. 165, text-fig. 3) the supposition that the supra-oral cover-plates in that species were suturally united to form a solid tegmen would be inconsistent with the presence of pores all round the peristome.

The Food-grooves of *Edrioaster* and many other Edrioasteroidea are so distinct that they call to mind those structures in Cystidea Rhombifera that used to be called "recumbent arms". Those, however, are produced by the proliferation of circumoral plates over the outside of the theca. The resemblance is really closer to the epithecal grooves of the Diploporita. Their anatomical relations, and, in *E. levis*, their connection with the interambulacrals, show that the floor-plates are part of the thecal wall, not different in origin from the other thecal plates. As in the Diploporita we see to have been the case, so in Edrioasteroidea we may infer that the grooves passed out over the theca from the angles of the mouth, and that as they became deeper and more fixed, and as the cover-plates increased in size, so the subjacent plates became regularized. That is one possible hypothesis, and it seems to be the one held by Dr. Foerste (1914, p. 425). Another hypothesis is that the grooves passed out from the angles of the mouth between the thecal plates and not over them. This view is suggested by the appearances in *Stromatocystis*, and would have the advantage of making the floor-plates a double series from the outset. The disadvantage is the great weakening of the peristomial region which the hypothesis implies.

In any case a stage was reached sooner or later in which the ciliated grooves, with the underlying extensions of the nervous and water-vascular systems, passed over the floor-plates and under the cover-plates as in Diploporita. But from the Diploporita all Edrioasteroidea differ in the absence of exothecal projections (brachioles) bordering the grooves or forming the ends of their branches. From this point of view alone the Edrioasteroidea present an ambulacral structure divergent from that of all other Pelmatozoa, and this is why they have certainly better claims than the Blastoidea, for instance, to rank as a separate class. In those Edrioasteroidea whose skeleton, like that of *Edrioaster*, bears witness to the presence of ampullae, this distinction is enhanced, not changed in character.

The structure of the Peristome has been described for *Edrioaster buchianus* (1900, p. 197, Pl. X, Fig. 2) and *E. bigsbyi* (1914, pp. 164–6, text-fig. 3, Pl. XIV, Fig. 2). It is clear that, as E. Billings noted in 1854, the gullet into which the food-grooves led passed into the stomach through a firmly-built ring or mouth-frame, of which the inner adcentral border turned down so as to form a rim, probably for the attachment of the stomach wall. As viewed from the oral aspect, after removal of all cover-plates, the chief elements of this frame appear to be five perradial plates, of which the exposed portions have a triangular outline. Viewed from the inside of the test, there are also seen to enter into this frame five interradial elements. In all the interradii except the posterior, and in all perradii, these elements appear to be formed of fused portions of floor-plates. In the posterior interradius there also enters into the frame a portion of the large interradial plate that is pierced by the hydropore-canal.

In the Agelacrinidae an essentially similar peristomial frame has been described, first, obscurely by Miller & Faber in a specimen of *Agelacrinus pileus* (1892 Journ. Cincinnati Soc. Nat. Hist., vol. 15, p. 85, pl. i, fig. 10), secondly, in more intelligent detail from the same specimen, as well as in a specimen of *Streptaster septembrachiatus* by Dr. A. F. Foerste (1914, op. cit., p. 427, pl. i, fig. 5A, pl. ii, fig. 4, and p. 429, pl. i, fig. 7A, pl. iv, fig. 2), who has also favoured me with explanatory diagrams (in litt., 18 Feb., 1915). In the Agelacrinidae, as previously remarked (Study VI, 1915, p. 55) the floor-plates are quadrangular and stretch right across the groove; they may be composed of fused pairs of floor-plates of *Edrioaster* type, but direct evidence for this is lacking. The proximal floor-plate in each ray widens at its proximal or adcentral end, so that these five plates meet, except in the posterior interradius. The adcentral borders of these plates also bend down into the thecal cavity. Thus is formed a roughly circular or sub-pentagonal mouth-frame, similar to that of *Edrioaster* and confirming the interpretation of the radial elements in that genus as fused floor-plates. The gap left in the posterior interradius is filled in by one (*A. pileus*) or possibly more (*Streptaster*) of the posterior peristomial interradial plates, just as in *Edrioaster*. For minor details reference must be made to Dr. Foerste's account; but two structural features seem to have an important bearing.

In the specimen of *Streptaster*, when the mouth-frame is viewed from the inner face, there is seen on the left side of the posterior interradius a curved process, apparently attached to the inner face of the tegmen. This separates "a vertical cavity, less than a millimeter in diameter, apparently leading to the oral surface of the theca" just on the posterior side of ray V, from "a broad inclined groove" leading towards the thecal cavity between rays IV and V. Dr. Foerste's suggestion that this groove served for the passage of the gut seems entirely justified, and confirms the view that the gut had a solar coil. The stereom process served, one may suppose, for the attachment of one end of the posterior mesentery; and the deep narrow passage on the posterior side of it, adjoining ray V, was probably for the passage of a hydropore-canal. That, at any rate, is where such a structure would have lain if it existed.

In the specimen of *Agelacrinus pileus*, the posterior element of the mouth-frame is ridged on its inner face "somewhat like a letter W, the sides of the letter abutting against the thickened inner margins of the adjacent proximal floor-plates" of rays I and V. The middle ridge of the W passes towards the centre of the tegmen; and towards almost the same point are directed similar ridges on the inner faces of the tegminal plates between rays III & IV and III & II respectively. This suggests that the large posterior plate is a compound structure, consisting partly of an interradial element, partly of portions of original paired floor-plates, and partly of the cover-plates which have been transformed on the exterior into the posterior tegminal. Adjoining the margin of this plate where it abuts on ray V, and involving the two proximal cover-plates on the adanal side of that ray, is "a peculiar margined depression". If, as Dr. Foerste suggests, "a duct passed by this path," then the duct in question would most naturally be the hydropore-canal.

The Relations of the Water-vascular System are of much morphological importance. The most natural interpretation of the appearances in the Edrioasteridae is that the perradial water-vessels lay at the bottom of the subvective grooves, on the ventral side of the abutting floor-plates, and that each gave off alternate branches to podia placed near the outer margin, and that each branch was also connected, through the pore between adjacent floor-plates, with an ampulla lying below (dorsal to) the subvective skeleton. This interpretation will be confirmed by comparison with a modern starfish. The perradial vessels passed to the peristome, and *Edrioaster buchianus* has already yielded evidence (Study II, 1900, p. 198) to show that they were there connected to form a hydrocircus surrounding the opening to the gullet, just above the mouth-frame. The hydropore lay in the posterior interradius, close to ray V, and passed through one or more interradial plates of the theca in a sloping direction from right to left. This direction indicates some torsion of the hydropore-canal and presumably also of the stone-canal, both of which must have been in the thecal cavity. Precisely where they became connected with the hydrocircus we cannot say, but it is plain that connection could readily have been effected by anyone of the ampullar or podial pores, and we may here recall that E. Billings observed a pore in the posterior angle to be larger than the others (Study IV, 1914, p. 164).

In the Agelacrinidae there is no such direct structural evidence for the position or even for the existence of perradial canals, not to mention podia. The shape of the cover-plates in most genera does, however, seem consistent with (one is tempted to say "calculated for") the extrusion of podia between them, and it seems natural to suppose that these structures were present, though unprovided with intra-thecal ampullae. An external hydropore has not as yet been detected, but it is conceivable that the hydrocircus opened into the oral vestibule, and that it may have been connected with some canal passing up in the posterior interradius (*vide supra*).

Edrioaster, *Agelacrinus*, and *Steganoblastus* present three modifications of an original subvective skeleton consisting of paired alternating floor-plates and cover-plates. In *Agelacrinus*, where ampullae were still unformed, the floor-plates became partly fused, but were still separated at intervals so as to maintain some flexibility. In *Edrioaster* the development of ampullae and more vigorous podia produced pores and combined with the general flexibility of the test to keep the original floor-plates distinct, except in the mouth-frame. In *Steganoblastus* the ampullae and podia remained, but the floor-plates fused and, in correlation with the rigidity of the theca, formed a single piece stretching right along under the groove.

IV.—A Contribution to the Petrology of North-Western Angola.

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

(*Continued from the May Number, p. 232.*)

4. Ægirine-Riebeckite Granite from the Lower Congo. (Pl. XI, Fig. 1.)

This remarkable rock occurs as a marginal phase of the granulitic albite granites which are found between Noqui and kilometre 16 on the road to San Salvador. In the hand-specimen it shows a fine-grained slightly foliated structure with a characteristic 'pepper and salt' appearance, due to the sprinkling of lustrous black plates of riebeckite among iron-stained granular crystals of quartz and felspar. A few small porphyritic crystals of orthoclase are embedded in the main mass of the rock, making up approximately 15 per cent of the whole.

The minerals present, and their relative proportions by weight, measured by the Rosiwal method, are as follows:—

	Quartz	32
Alkalic Felspars	Albite, Microcline	23
	Orthoclase microperthite	15
	Microcline microperthite	10
	Riebeckite	16
	Ægirine	4
Accessory Minerals	Zircon, Ilmenite, Limonite, Sericite or kaolin (?)	n.d.
	Total	100

A separation was effected by means of Klein's solution, which was gradually diluted with water. Specific gravity measurements were made with a Westphal balance at each critical point.

Specific Gravity.	*Minerals.*
3·441	Ægirine (3·5) sank.
3·381	Riebeckite sank.
2·645	Quartz sank.
2·599	Albite sank.
2·545	Orthoclase and microcline sank.

Special care was taken to examine the grains which fell at 2·645 for oligoclase, but none could be detected. The absence of oligoclase was further verified by refractive index measurements. Using clove-oil ($\mu = 1·544$) only quartz among the colourless essential minerals give a higher value. Using monochlor benzine ($\mu = 1·527$), albite gave a higher value, orthoclase and microcline a lower one.

The felspars, with the exception of the larger microperthite crystals, form with quartz a fine-grained glassy mosaic, the constituents of which give sharp extinctions between crossed nicols with no trace of strain shadows. The porphyritic crystals, on the contrary, do show strain phenomena. They have ill-defined borders, owing to interlocking with the surrounding mosaic, and in one case it was noticed that a long tongue of the latter, heavily charged with vermicular limonite and minute zircons, had cut transversely across the crystal. The porphyritic crystals are twinned according to the Carlsbad law, and are made up of orthoclase with microperthitic streaks of albite. Inclusions of riebeckite needles, and patches and blebs of limonite follow the lines of perthitic intergrowth, and are commonly, but not invariably, arranged in linear groups. Here and there irregular aggregates of an indeterminable mineral, which may be kaolin or sericite, can be seen. Similar inclusions occur in the microcline and albite of the mosaic, but they are less abundant than in the larger perthites.

Intermediate in size between the porphyritic crystals and those of the mosaic are a few allotriomorphic individuals of microcline perthite. The 'cross-hatching' of the microcline is somewhat patchy, and may be absent altogether. Feeble strain shadows are seen in some cases, but in others the extinction is sharp.

The felspars of the mosaic are exclusively microcline and albite. An analysis of the rock indicates that the albite molecule may be accompanied by a very small proportion of anorthite. Making allowance for the fact that more than half of the CaO in the rock is probably present in riebeckite and ægirine, the albite can scarcely be more calcic than $Ab_{96}\,An_4$. Both orthoclase and microperthite are entirely absent from the mosaic, and microcline is much less abundant than albite. The felspars are generally allotriomorphic, but sometimes they exhibit crystal planes in contact with quartz.

The larger felspar crystals are predominantly of orthoclase, accompanied by a little perthitic albite; those of intermediate size are chiefly of microcline, again accompanied by perthitic albite. Among the smaller individuals albite is predominant, microcline is subsidiary, and perthitic intergrowths are absent. It would be unwise to assume too much from a single specimen of the rock, but the restriction of strain phenomena to the larger crystals suggests that the mosaic felspars may be partly the result of the granulation, recrystallization, and albitization of the older orthoclase perthites. A similar explanation of the structures and composition of the Quincy riebeckite granite has been given by Warren.[1]

Quartz is the most abundant mineral in the rock, making up about 60 per cent of the colourless constituents of the mosaic. It is present in allotriomorphic equidimensional grains which exhibit no unusual features.

Riebeckite is present to the extent of about 16 per cent of the whole rock, an unusually high proportion for a rock of this type. It varies in size from tiny microscopic needles and irregular shreds to larger crystals which tend towards a prismatic habit, but which generally have ragged edges. In transverse sections the average area is much the same as that of the quartz and felspars of the mosaic, but it is subject to greater variation. The prism and clinopinacoid edges can sometimes be identified. Longitudinal sections are elongated, the

[1] C. H. Warren, Proc. Am. Acad. Arts and Sci., vol. xlix, No. 5, p. 215, 1913.

maximum dimension being about two millimetres. Intergrowths with ægirine were not observed, but occasionally a thin fringe of ægirine, or of minute fibres of limonite, separates the riebeckite from the other minerals. Patchy inclusions of quartz and felspar, minute prisms of zircon, and small grains of ilmenite(?) break up the continuity of the riebeckite individuals, but the mineral has not the spongy appearance which is its customary habit.

The pleochroism and optical orientation were determined from longitudinal and transverse sections. Faint indications of biaxial interference figures were seen in the latter in very thin sections, from which it was determined that the plane of the optic axis bisects the *acute* angle between the cleavages. The maximum extinction angle $X \wedge c$ is about 5°. The pleochroism is as follows: X (nearly $= c$), deep ultramarine blue; Y (nearly $= a$), yellowish green; Z ($= b$), smoky greenish blue. $Z > X > Y$. The colour is generally patchy, and grey and violet tints are sometimes seen in intermediate positions between X and Y. The birefringence is very low.

In almost every respect, and notably in the position of the optic axial plane, which is parallel to the orthopinacoid, the Angola riebeckite bears a striking resemblance to that of the Quincy granites.[1] In the latter case the composition was approximately $Na_2\,Fe_2\,(Si\,O_3)_4$, 42 per cent; $R_4\,(Si\,O_3)_4$, 56 per cent, in which R is chiefly Fe accompanied by smaller amounts of Ca, Mn, and Mg; with excess of 2 per cent of $Si\,O_2$. This is an unusually high percentage of the $R_4\,(Si\,O_3)_4$ molecule, but the exceptionally high content of ferrous iron in the Angola rock suggests that there the $R_4\,(Si\,O_3)_4$ molecule is equally abundant. Unfortunately the material available was insufficient to allow an analysis of the separated riebeckite to be made.

Ægirine makes up about 4 per cent of the rock. The crystals are very irregular and broken in appearance, except where the mineral occurs as tiny inclusions which are elongated along the vertical axis. There is a tendency for small fragmentary ægirines to occur in groups which extinguish nearly, but not perfectly, as a whole. Many of the crystals are veined with ferruginous matter, which also collects round the edges in thin fibres and minute acicular projections. The pleochroism is as follows: X (nearly $= c$), grass green or blue green; Y ($= b$), yellow green; Z (nearly $= a$), straw to pale yellow green. $X > Y > Z$. The maximum extinction angle between X and c is about 9°, showing that the ægirine is not quite pure.

Zircon is present in extremely minute crystals which are present as inclusions in all the minerals, but more particularly in the soda-bearing minerals. As in the case of rockallite[2] the total amount of zircon present is manifestly insufficient to account for the percentage of zirconia found in the rock by analysis. In this case the zirconia must enter into the composition of the riebeckite. The association of zirconia with riebeckite has been frequently pointed out.[3] Parisite,

[1] Warren & Palache, Proc. Am. Acad. Arts and Sci., vol. xlvii, No. 4, p. 152, 1911.

[2] Washington, Q.J.G.S., vol. lxx, p. 298, 1914.

[3] For references and discussion see Murgoci, *Am. Journ. Sci.*, vol. xx, p. 137, 1905.

which is a characteristic associate of riebeckite, though a very rare mineral, was looked for, but could not be identified with certainty. Tiny grains of ilmenite peripherally altered to leucoxene are present, included in or near to riebeckite.

Ferruginous stains occupy the borders between many of the crystals, and vermicular aggregates and fibrous coatings of the same material have already been mentioned. Both the colour, and the excess of combined water in the rock over that required for riebeckite, point to limonite as the identity of this mineral. The rock shows no trace of weathering alteration, and it is possible, as Murgoci has suggested,[1] that the limonite is primary, and that it now directs attention to areas which at the moment of consolidation were still more or less impregnated with iron compounds and water vapours.

Chemical Characters and Classification.—A chemical analysis of the rock was made by the methods advocated by Washington. The results are given below, together with the norm and the position of the rock in the Quantitative Classification. The rock falls into the subrang Varingose (II, 3, 1, 3) on the side of Grorudose (II, 4, 1, 3), which differs from the former only in the inferior ratio of quartz to felspar.

Analysis.		*Norm.*		
SiO_2	74·66	Quartz	35·38	Salic = 83·10
Al_2O_3	8·85	Orthoclase	26·13	
Fe_2O_3	3·26	Albite	20·96	
FeO	3·54	Zircon	0·63	
MgO	0·09			
CaO	0·53	Acmite	8·78	Femic = 16·67
Na_2O	3·68	Diopside	2·23	
K_2O	4·46	Hypersthene[2]	4·82	
H_2O (115°+)	0·67	Magnetite	0·23	
H_2O (115°−)	0·08	Ilmenite	0·61	
TiO_2	0·32			
ZrO_2	0·51		99·77	
Total	100·65			
Sp.gr.	2·55			

Class II, Dosalic.
Order 3. Quarfelic.
Rang 1, Peralkalic.
Subrang 3, Sodipotassic.
II, 3, 1, 3, VARINGOSE.

A number of analyses of other riebeckite and ægirine granites is listed below for comparison with the Angola example. It will be noticed that with the incoming of riebeckite the proportion of ferrous iron relative to ferric is increased, and moreover that a high proportion of ferrous iron is consistently accompanied by a superiority of potash over soda. Analysis III, that of the Angola rock, falls into the same subrang as that of the Grorudite from Varingskollen. The two analyses are strikingly similar, and the total iron contents are practically identical. There is, however, a sharp difference in the relative proportions of ferrous and ferric iron, a difference which

[1] Murgoci, p. 145.
[2] Practically all $FeSiO_3$.

corresponds to the distinction in mineral composition between the two rocks. Compared with other riebeckite granites, it is clear from analyses, modes, and norms that the Angola rock is richer in riebeckite than any other granite hitherto described.

Constituents.	Ægirine-acmite Granites.		Ægirine-Riebeckite Granites.				Riebeckite Granites.	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	69·80	74·35	74·66	73·80	75·25	74·86	76·49	68·54
Al_2O_3	5·10	8·73	8·85	11·90	11·60	11·61	11·89	15·47
Fe_2O_3	13·23	5·84	3·26	1·90	0·78	2·29	1·16	2·03
FeO	0·78	1·00	3·54	1·91	3·00	1·25	1·56	2·09
MgO	0·11	0·07	0·09	0·33	0·39	0·05	tr.	0·21
CaO	0·72	0·45	0·53	0·30	0·70	0·41	0·14	0·30
Na_2O	8·04	4·51	3·68	5·05	3·98	4·30	4·03	5·68
K_2O	0·22	3·96	4·46	4·93	4·20	4·64	5·00	5·75
H_2O+	0·46	0·25	0·67	0·13	—	0·31	0·38	0·59
H_2O-	0·31	—	0·08	0·04	—	0·04	0·12	
TiO_2	0·34	—	0·32	0·23	0·19	0·20	tr.	0·14
ZrO_2	1·17	—	0·51	0·04	—	0·20	—	—
P_2O_5	0·07	—	n.d.	—	—	tr.	—	0·10
Ce_2O_3	0·37	—	n.d.	0·04	—	—	—	—
MnO	0·12	0·22	tr.	0·12	—	0·02	tr.	—
Totals	100·84	99·38	100·65	100·72	100·09	100·18	100·77	100·90
Magmatic Symbols &	III, 3, 1, 3	II, 3, 1, 3	II, 3, 1, 3	I, 4, 1, 3	I, 4, 1, 3	I, 4. 1, 3	I, 4, 1, 3	I, 4, 1, 3
Names.	Rockallose.	Varingose.		Liparose.				

I. *Rockallite.* Rockall. H. S. Washington, analyst. Q.J.G.S., vol. lxx, p. 297, 1914.
II. *Grorudite.* Varingskollen, Norway. G. Särnström, analyst. Brögger, *Zeit. Krist.*, vol. xvi, p. 66, 1890.
III. *Ægirine-Riebeckite Granite.* Congo, Angola. Arthur Holmes, analyst.
IV. *Ægirine-riebeckite gneiss.* Carn Chuinneag, Ross-shire. W. Pollard, analyst. Mem. Geol. Surv. Scot., Sheet 93, p. 92, 1912.
V. *Ægirine-Riebeckite Granite.* Zinder. Between Lake Tchad and Sokoto. Lacroix, C.R., vol. cxl, p. 22, 1905.
VI. *Ægirine-Riebeckite Granite.* Quincy, Mass. Mean of three analyses by C. H. Warren and H. S. Washington. Warren, Proc. Am. Acad. Arts and Sci., vol. xlix, p. 227, 1913.
VII. *Paisanite.* Magnolia, Essex Co., Mass. H. S. Washington, analyst. *Journ. Geol.*, vol. vii, p. 113, 1899.
VIII. *Riebeckite Granite.* Ekona, Sungale, Kamerun. Rosenbusch, loc. cit.

Corresponding with the high riebeckite content of the rock is its comparative richness in zirconia. The ratio of riebeckite to zirconia in the Quincy granite (analysis VI) is practically identical with that of the Congo rock.

Granites containing both riebeckite and ægirite or acmite are somewhat rare, and in addition to the four examples of which analyses have been quoted the only others of which I have succeeded in finding a record are from the following localities:—

Dahamis, Socotra: riebeckite-acmite granite.[1]
Cevadaes, Portugal: ægirine-riebeckite granulite.[2]
Narsarsuk, Greenland: ægirine-riebeckite granite.[3]
Shira and Kila, Northern Nigeria: ægirine-riebeckite granites.[4]
Ampasibitika, Madagascar: ægirine-riebeckite granite.[5]

Although the ages of these nine rocks are not yet known except within broad limits, it is clear that they range from late Archæan to early Tertiary, and it is interesting to notice that, rare as it is, ægirine-riebeckite granite is a type which has recurred at widely different periods and in widely separated localities.

Granites containing riebeckite or ægirine are not rare in West Africa. They occur with ægirine rhyolites and alkaline trachytes in the Shari basin (Mburao and Melfi) and at Hadj el Hamis on the south-east of Lake Tchad.[6] At Zinder and Mounio, west of Tchad, riebeckite, ægirine, and ægirine-riebeckite granites are associated with rhyolites of corresponding composition,[7] and further to the north, in the Saharan complexes of Ahaggar and Air, ægirine rhyolites are found.[8] Riebeckite granites are known from Feta in Dahomey, and they are well represented in Nigeria in the Gurkawa Hills, on the Bauchi plateau, near the borders of Bauchi and Kano, and at Shira in Katajum.[9] Unfortunately the ages of these rocks are not yet known with certainty. The volcanic rocks appear to be early Tertiary, but the granites may lie anywhere between late Pre-Cambrian and early Tertiary.

EXPLANATION OF PLATE XI.

Fig. 1.—Ægirine-riebeckite Granite, near kilometre 16, on the road from Noqui to San Salvador, Congo, Angola, showing riebeckite in longitudinal sections, and allotriomorphic quartz and felspar with films of limonite between adjacent individuals.

Fig. 2.—Nepheline Syenite (Foyaite), near kilometre 24, on the road from Senza do Itombe to Bango, Loanda, Angola; showing nepheline (clear except along cracks) and orthoclase (cloudy), with a characteristic group of ægirine augite bordered with hastingsite and sphene.

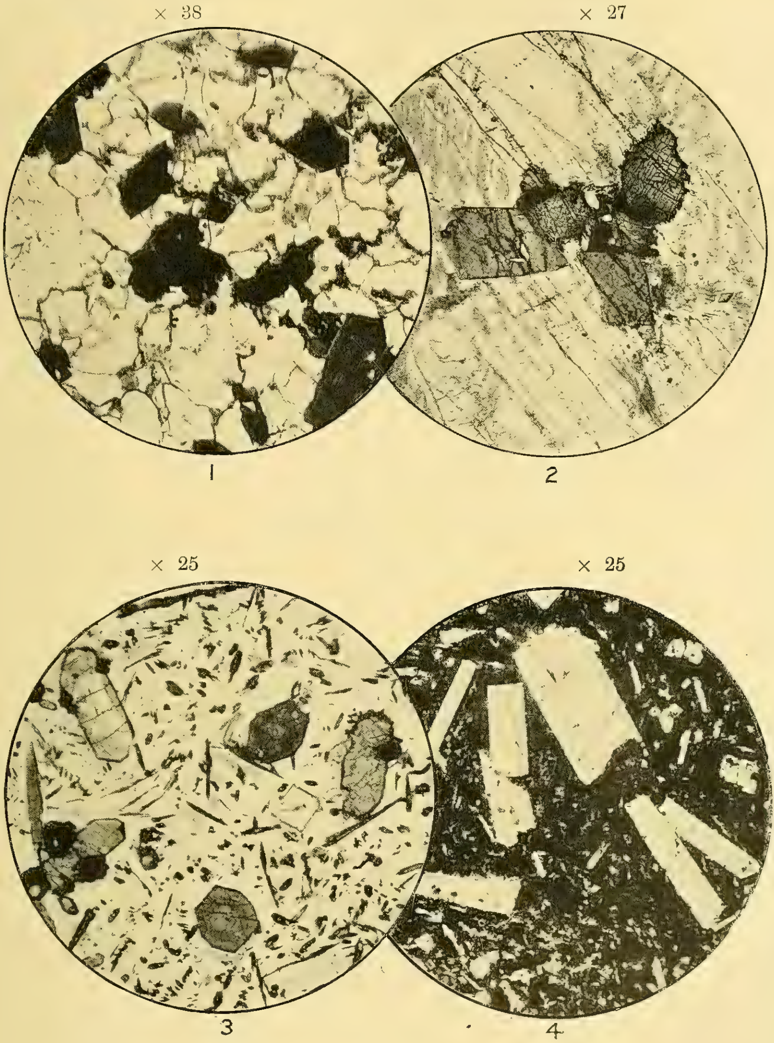
Fig. 3.—Nepheline Monchiquite, near kilometre 20, on the Senza-Bango road, showing phenocrysts of amphiboles and pyroxenes and wisp-like ferns embedded in a clear groundmass of nepheline and of what is probably analcime.

Fig. 4.—Nepheline Phenolite, near kilometre 22, on the Senza-Bango road, showing phenocrysts of nepheline in a dark groundmass which includes ægirine augite and a yellow-brown isotropic base.

Ordinary light and magnification 40 in each case.

The photo-micrographs were made for me by Mr. G. S. Sweeting, of the Geological Department of the Imperial College, to whom my best thanks are due.

[1] Rosenbusch, *Elemente d. Gesteinslehre*, p. 86, 1910. Analysis by Ludwig.
[2] Osann, *Neu. Jahre Min. Geol.*, etc., 1907, p. 109 (2); de Sousa, C.R., vol. clvii, p. 1451, 1913.
[3] Flink and Böggild, *Meddelelser om Grœnland*, p. 24, 1899.
[4] Falconer, *The Geology and Geography of Northern Nigeria*, p. 133, 1911.
[5] Lacroix, Nouv. Arch. Mus. Hist. Nat., sér. IV, p. 164, 1902.
[6] Gentil & Freydenberg, Bull. Soc. Géol. France, sér. IV, viii, p. 35, 1908.
[7] Chudeau, Sah. Lond. 1909, p. 266.
[8] Chudeau, op. cit., p. 258.
[9] Falconer, *The Geology of Northern Nigeria*, pp. 133–4. See p. 135 for other references.



ALKALINE IGNEOUS ROCKS from North-Western Angola.

V.—"Radio-activity and the Earth's Thermal History": A Criticism.

By Professor A. P. Coleman, M.A., Ph.D., F.R.S., University of Toronto.

In the very interesting paper by Mr. Arthur Holmes on "Radio-activity and the Earth's Thermal History", in the Geological Magazine for February and March, it is assumed that in Archæan times there was "a widespread molten condition at no very great depth" below the earth's surface, and in the final conclusions the statement is made that "geological and other evidence points favourably to the traditional view that the earth's crust was initially in a molten state". The results of recent work on the Archæan of Canada do not bear out this traditional view of the conditions of the earth's earliest known geological period, and it may not be amiss to suggest some points that decidedly conflict with it.

The earliest rocks known on the Canadian Shield are the Coutchiching, the Keewatin, and the Grenville Series. The Coutchiching consists entirely of metamorphosed muddy and sandy sediments, the Keewatin includes mainly volcanics, but also considerable amounts of sediments, and the Grenville is essentially sedimentary and consists largely of limestone. These three groups of rocks seem to have been formed in succession with no great break in time. Lawson has shown that the Coutchiching, in part at least, underlies the Keewatin, and Miller and Knight have found that in Eastern Ontario the Grenville overlies Keewatin volcanics, apparently conformably. All of them antedate the batholithic eruptives, which have upheaved and penetrated them. They were therefore deposited before the earliest known acid plutonics, generally called Laurentian, had begun their ascent beneath the Archæan mountain ranges.

Lawson gives the Coutchiching sediments of Rainy Lake a thickness of 4½ miles, and the Keewatin volcanics he describes as equally thick. In other Keewatin regions 1,000 or more feet of "iron formation" as well as important amounts of other sediments are found associated with the Keewatin and should be added to the total. The Grenville of the Haliburton region in Eastern Ontario is believed by Adams to be 90,000 feet in thickness, the greater part consisting of limestones.

It will be seen, then, that before the first known batholithic mountain building began there were on the surface of the earth many thousands of feet of sedimentary and volcanic rocks. It may be objected that the thickness of these ancient and much metamorphosed rocks has perhaps been over-estimated, but it must be remembered on the other hand that they are known to us only as remnants, since the great mountain ranges of the early Archæan had been reduced to a peneplain before the beginning of the Huronian. It is most unlikely that the whole thickness of these rocks has been anywhere preserved.

But there is another point of equal importance to be considered. The floor on which these great beds of sediments and volcanics were deposited has nowhere been found, though it must have been thick and solid to support their weight; and the great areas of dry land whose weathering furnished the hundreds of cubic miles of mud and sand of the sedimentary rocks have likewise vanished. There must have been thousands of feet of solid rock beneath the seas and the continents of the time, but these seem to have been melted and set in motion as the materials of the batholithic granites and syenites that came later. The batholiths have even stoped down and encroached upon the lower portions of the Coutchiching, Keewatin, and Grenville as well; so that to find the original thickness of the first known crust of the earth one must add many thousands of feet to the estimates given above.

Finally, it must be recalled that water existed as a liquid at the very beginning. The rocks forming the basins were not warm enough to evaporate the seas of the time; and in both the Keewatin and the Grenville there are important beds of sediments containing five or ten per cent of carbon, strongly suggesting algæ or some other form of plant life. It may be that the limestones also were formed by the aid of plants or animals. If life existed in the seas, as seems very probable, the temperature of the earth's surface was not higher than living beings can endure, and we may fairly assume that conditions were not widely different from those of later geological periods.

With conditions such as have just been described in early Archæan time there is no good reason to suppose that the molten magma was near the surface. It was probably as far below as in later ages or at present. The great abundance of Archæan granites and orthogneisses simply means that, in the most ancient regions of the world, erosion has gone to greater depths than elsewhere. The same types of plutonic rocks are found at many later ages, though naturally they are not so extensively exposed, since the overlying rocks have undergone less destruction. Batholiths of Mesozoic granite and diorite cover 50,000 square miles of the coast ranges of British Columbia and have precisely the same habit as the Laurentian. There is, in fact, no geologic reason for supposing that the earth had a higher temperature in the Archæan than at any later time. If the earth was ever a molten globe it had so far cooled down in the earliest known geological times that life probably existed, that water and air did their work just as in later ages, and that an immense thickness of sediments and lavas could be deposited on a firm foundation of still earlier rocks.

VI.—The Coastal Series of Sediments in the East Africa Protectorate.

By H. B. Maufe, B.A., F.G.S., Director of the Geological Survey of Southern Rhodesia.

In his report on "The Coal Resources of the East Africa Protectorate" published in the Twelfth International Geological Congress' *The Coal Resources of the World* (vol. ii, p. 381), Dr. J. W. Evans discusses evidence bearing on the existence of coal in the Taru Grits, which form the lowest member of the coastal series of sediments in the East Africa Protectorate. Referring to a report of mine,[1] he

[1] Report relating to the Geology of the East Africa Protectorate. *Colonial Reports, Miscellaneous*, No. 45, 1908.

remarks that I believe them to be of Karroo age, and then says, "E. Fraas, who subsequently made a brief examination of the line of railway, and whose account of the geology of the region differs in many respects from that of Maufe, refers them to the Middle Dogger (Inferior Oolite)."[1]

I cannot explain how Fraas' paper came to be overlooked by me, or that author's reading of the structure and succession would certainly have been challenged at once. Fraas' examination was made whilst detained in Mombasa for a day or two waiting for a steamer. He apparently travelled up and down the Uganda Railway by train, and was able to make excursions from a couple of the stations. I had the advantage of several weeks on the ground, both trolleyed and walked the whole line, and made several traverses out on both sides where sections might be seen on the flanks of valleys.

Between Voi (mile 102) and Kilindini on the coast Fraas makes seven rock groups, which in ascending succession are as follows: (1) Crystalline basal rocks, (2) Karroo sandstone, (3) Middle Dogger, (4) Upper Dogger, (5) Malm, (6) Cretaceous sandstone, (7) Pleistocene reef limestone.

According to Fraas' description and section the crystalline basal rocks crop out at Voi, and the dip being eastwards towards the coasts the other groups outcrop in order in that direction with the exception of (6) Cretaceous sandstone, which, owing to a supposed flattening of the dip, does not reach the coast. The Pleistocene reef (7) rests unconformably against his (5) Malm.

Between Voi and Maungu, the next station towards the coast at mile 84, Fraas states that (2) Karroo sandstone crops out, and also says, "South of the railway the Maungu Mountains rapidly rise to a height of 1,000 metres. We easily recognize these as sandstone mountains with horizontal stratification, and a light-coloured, cross-grained sandstone is to be seen along the railway." I climbed these 'mountains' and found them to consist of a foliated hornblende-biotite-gneiss (Report, p. 19). Also, I am sure the whole distance from Voi to beyond Maungu is underlain by gneiss, and any sandstone seen beside the railway must have been brought there for construction.

At Mombasa Fraas saw a big trunk of silicified wood which he was told came from this region. The trunk is without doubt one which I dug out of his (6) Cretaceous sandstone and took down to Mombasa station. (Report, p. 9.)

Around Samburu (mile 41) he notes the hard micaceous sandstones which he says are (3) Middle Dogger. These are my Taru Grits, which were being quarried for the Kilindini harbour works. He examined them more closely there, and found poor impressions of Calamite-like stems, and fragmentary leaf-remains, also one cross-section of a Belemnite and one skeleton impression of an Ammonite. I saw only obscure plant-remains and black carbonaceous specks in the beds at Samburu. Beyond Samburu Fraas identifies from the train the sandstones of the Upper Dogger (4). These are probably the lower part of the Maji-ya-Chumvi Beds, in which I found *Thuyites* and *Carpolites*.

[1] *Centralblatt für Mineralogie*, etc., 1908, p. 641.

At the station of Maji-ya-Chumvi (mile 33) Fraas notes greasy brown marls, said to be of Oxford and Kimmeridge age (group 5), which without doubt are a part of my Maji-ya-Chumvi Beds. Fraas saw no fossils here, but identifies them with a part of the marine fossiliferous Changamwe Shales of Mombasa Harbour. Not only are they distinct lithologically, in being dull greenish mudstones with numerous thin beds of very hard sandstone, but in place of the Ammonites and Belemnites found in the Changamwe Shales I obtained *Estheria* near Maji-ya-Chumvi. After the description by Mr. R. B. Newton of a new species of *Estheriella* discovered by Messrs. Andrew and Bailey in the Karroo rocks of Nyassaland,[1] Mr. Newton kindly examined the Maji-ya-Chumvi specimens, and wrote: "I am inclined to regard them as carapaces of a form closely allied to *Estheria greyi*, T. Rupert Jones, from Cradock, South Africa. I should regard them also as of similar age to those found by Molyneux in Rhodesia, as well as those discovered by Andrew & Bailey in Nyasaland." This I think makes it clear that the Maji-ya-Chumvi Beds cannot be correlated with the marine Changamwe Shales of Upper Jurassic age.

Above the Maji-ya-Chumvi Beds come sandstones, which Fraas, as a result of his identification discussed in the preceding paragraph, places above the Changamwe Shales and calls Cretaceous. These sandstones were divided by me into two groups, the Mariakani Sandstones below and the Mazeras Sandstones above. I found that the Mazeras Sandstones dipped below the Changamwe Shales, a clear section being seen in the estuary of the Mwachi River, south of the railway. Fraas' statement that the sandstones overlie the shales and cap the ridge along which the railway runs from Mazeras down to Changamwe is contrary to fact. The Shales at Changamwe are covered only by 6 or 8 feet of loam, which extends in this manner inland for 5 miles. The shales then appear on the surface and in cuttings for about 2 miles, when the upper beds of the Mazeras Sandstones rise from beneath them. The dip of the shales in this section is much above the average, being often 25° instead of the usual 10°. Shortly after passing on to the Mazeras Sandstone the dip flattens and is less than the normal. The overlooking of this change of dip has probably been the cause of the error in supposing that the sandstones overlay the shales with marine fossils. The presence of silicified wood, as noted above, in these sandstones, and their interstratification with bright green and purple sandstones point to the persistence of lagoonary or continental conditions until the close of the period of their deposition. Marine conditions come on for the first time on this coast with the Changamwe Shales, for near their base are two beds of limestone, the upper of which contains an unidentified lamellibranch. It is quite possible that this limestone is on the same horizon as the fossiliferous Bathonian limestone, apparently faulted in amongst Upper Jurassic shales, about 5 kilometres inland from Tanga, German East Africa.[2] The fossils which Fraas actually obtained all came from the well-known locality on the

[1] Quart. Journ. Geol. Soc., vol. lxvi, p. 244, 1910.
[2] W. Koert, *Zeitsch. der deutsch. geol. Ges.*, vol. lxi, p. 150, 1904.

Upper Jurassic horizons high up in the Changamwe Shales.[1] He obtained no more marine fossils from any of his supposed Cretaceous Malm, Upper Dogger, or Middle Dogger horizons anywhere inland from Mazeras, with the exception of the cross-section of a Belemnite and skeleton impression of an Ammonite, mentioned above as from material brought down to Kilindini harbour works. As the supposed horizon is several hundred feet below beds containing *Estheria*, it may be assumed that, if the identification of Belemnite and Ammonite is correct, the material has been referred to a wrong horizon, even as the fossil trunk brought down at Mombasa was thought to come from the Maungu gneiss.

Lamellibranchs (*Exogyra*, etc.), claimed to indicate an Aptian horizon, have been found north of Mombasa Island, but they were obtained from the top of the Changamwe Shales, not from the Mazeras Sandstones. No palæontological evidence exists for believing that Cretaceous rocks are exposed on the line of the Uganda Railway. On the other hand, from the gneiss inland to the coast there is an upward succession of grits and sandstones with shales, containing only plant-remains and *Estheria*, until the limestones at the base of the Changamwe Shales are reached, when marine fossils appear for the first time. The age of the lowest marine horizon has not been determined, but the higher fossiliferous beds indicate Upper Jurassic.

Professor Haug has inserted Fraas' horizontal section in his *Traité de Géologie*, vol. ii, p. 1043, but the accompanying description, giving lists of marine fossils of Bathonian, Callovian, and Oxfordian ages, refer to discoveries said to have been made in German East Africa, and is consequently most misleading. One would think that *Pseudomonotis echinata* had been found where gneiss actually crops out, and that Callovian fossils had been obtained from beds in which I obtained *Estheria* and *Thuyites*.

REVIEWS.

I.—Physical Geography. By Philip Lake, M.A. pp. xx+324. Cambridge University Press, 1915.

THIS textbook of Physical Geography is intended for the more advanced students in schools, yet its standard is sufficiently high to be of value to teachers as well. Since the author is both a practical geographer and geologist, as well as a teacher, we find that his treatment of the subject maintains a fairly even balance between these two branches of science.

The subject of environment, or the influence of Nature, and contact with other beings, upon the individual, is not discussed: the book, therefore, lacks the human element, and may prove a disappointment to a certain section of the geographical school, which at times is rather apt to construct plausible theories based upon insecure foundations. Mr. Lake has rather aimed at instilling into his readers a fairly deep knowledge of the natural phenomena likely to be experienced at any particular part of the globe, leaving the effects of environment to be deduced by the students themselves.

[1] Futterer, *Zeitsch. der deutsch. geol. Ges.*, vol. xlvi, p. 1, 1893.

The book is divided into three parts, dealing respectively with the atmosphere, the ocean, and the land. Of these, the first part (114 pp.) is largely meteorology, which receives much fuller treatment than is usual in a textbook of this class. It is perhaps all to the good, for meteorology is a branch of the subject which has been much neglected in the past, whilst recent advances in our knowledge of the atmosphere throw welcome light upon that varying combination of phenomena we call *weather*, and help us to value rightly the processes of *weathering* and *sculpture* of the rocks in different parts of the world. The influence of atmospheric pressure upon the weather is clearly propounded, and the migrations and changes of the belts of pressure, wind, and rain, with the apparent movements of the sun, are well described and illustrated by diagrams.

The part dealing with the ocean is shorter in length (78 pp.), but quite adequate. A valuable chapter is that upon waves and tides, with a special section devoted to those in British seas.

Although the third part of the book is the longest (125 pp.), we notice in it signs of great compression, as if the author had been compelled to reduce his manuscript to a much smaller compass than he desired. Some sections, therefore, are poor, and the manner of expression not always happy. Thus, in describing faults, reversed faults are omitted, although thrust-planes are mentioned. A better geological section than that of the thrust-plane of the Ardennes and Belgian Coal-field (is this a 'war' section ?) might have been chosen from the North-West Highlands.

The differences between local 'volcanic-quakes' and the great 'earth-shakers' are not made clear in the description of earthquakes.

In the chapter on rivers there is again ambiguity, owing to want of clarity of expression, especially in sections dealing with the erosion of a river and grading of the river channel. One of the best chapters in the book is that dealing with the development of river-systems, those of Northumberland, the Humber, and the Weald receiving special notice.

Under "Snow and Ice" glaciers receive little attention. It should be pointed out that the largest (Antarctic) bergs are composed of snow, and float with considerably more than one-ninth of their bulk above water.

In the chapter on volcanoes more might have been said about the ancient volcanoes of the British Isles. It seems necessary to emphasize that most of our mountains of volcanic origin are merely carved out of piles of volcanic debris. To many people a cwm, or corrie, in a shapely hill, must be an old volcanic vent.

An appendix of C.G.S. units used by the Meteorological Office in its daily weather report, a list of works of reference, and an index conclude a book that can be thoroughly recommended for the purpose for which it was written. The photographic illustrations are good, but too few in number; they are, however, supplemented by many well-drawn figures in the text, and seven world-maps dealing with pressure, temperature, and rainfall.

B. S.

II.—The Geology of Caithness. By C. B. Crampton and R. G. Carruthers; with contributions by John Horne, B. M. Peach, John S. Flett, and E. M. Anderson. Memoirs of the Geological Survey of Scotland (Sheets 110 and 116, with parts of 109, 115, and 117). pp. viii and 194. 1914.

THE appearance of this memoir marks an important advance in our knowledge of the geology of the north-east of Scotland. It deals mainly with the Caithness Flags and the strata associated with them, freshwater rocks of exceptional lithological character, and presenting problems of the greatest interest. Dr. Strahan tells us in his preface that the survey was long in progress, so long that as the services of many of those who took part in it were no longer available some re-examination of the area mapped by them became necessary, conditions unfavourable for uniformity and completeness, but they have not seriously affected the value of the work.

In his introductory chapter Dr. Flett formally accepts the Middle Old Red Sandstone age of the Orcadian rocks, though there is nothing in the evidence at present available, which is inconsistent with an attribution of the unfossiliferous rocks below the unconformity at the base of the Berriedale and Ellensgoe conglomerates to the Lower Old Red Sandstone. Of especial interest is the regular rhythm of sedimentation in the Caithness Flags, each cycle having a thickness of from 35 to 65 feet. This recurrence is considered to be the result of warping, but it seems more probable that it is due to periodic variations in meteorological conditions. It is a great misfortune that the untimely death of Dr. Traquair has left the evidence for the zoning of these rocks by means of their fish-remains in an incomplete state. There can be no doubt that the special fauna of the John o' Groat's Beds is of true zonal significance, but it is by no means clear how far this is the case with other variations in the species of fish which are present. Full details are given of the important discovery of the Achanarras fauna at Niandt on the east coast. It is difficult, however, to correlate the account of the beds at Achanarras with that given by Dr. Traquair, who saw them under more favourable circumstances. This account might well have been reproduced, as the Proceedings of the Royal Physical Society of Edinburgh are not accessible to most readers. It is curious that capitals are retained in this memoir in specific names, though they have long since been abandoned in Survey memoirs dealing with England and Wales. A number of plant-remains have been described from the Caithness Flags, but the names of none of these appear in the memoir, though we are informed that the plants collected were submitted to Dr. Kidston for identification.

One of the most striking features of the Orcadian rocks of Caithness is their enormous thickness, which has been estimated at from 16,000 to 18,000 feet, which, however, includes 5,000 feet attributed to the Thurso Flags. The present writer has given reasons for believing that this is excessive, and the evidence furnished by the memoir points in the same direction. The question is complicated by the extent to which the rocks in the interior are obscured by Quaternary deposits, the repetition and lateral variation of lithological characters, the infrequency of fossils, and the possibility of the occurrence of undetected faults.

The igneous rocks intrusive in the Old Red Sandstone include monchiquite and nepheline basalt, allied to the dykes of the Orkneys.

Second only to the Orcadian rocks in interest are the glacial phenomena, which are dealt with in considerable detail, and a full account is given of the transported mass of Lower Cretaceous age found at Leavad. The absence in Caithness of the 100 foot and 50 foot raised beaches that are so characteristic of the Scottish coasts is attributed to a covering of ice, but it is possible that the former may be represented by the beach found at a height of from 5 to 8 feet above the sea, for there is evidence of recent depression.

The colour-printed sheets 110 and 116 mark a great advance on the hand-coloured sheet 115. It is a pity it was necessary to employ the dark tints which have been allocated to Devonian rocks and render the topography difficult to read, and the difficulty is increased by the shading indicating the Quaternary deposits. A small area south of the Stacks of Duncansby is wrongly coloured as Caithness Flags instead of John o' Groat's Sandstone. This has been set right in type, but was correctly mapped nearly a quarter of a century ago. It is interesting to note that after employing in turn white, black, and blue for faults the Survey has now adopted dark reddish brown for the same purpose. The only drawback is that it rather suggests igneous dykes.

J. W. E.

III.—Geological Model of the Assynt Mountains.

THE North-West Highlands of Scotland from the time of Macculloch onwards have excited the attention of British geologists; now, thanks to their labours, and not least to those of Drs. Peach and Horne, the region stands as a type for the study of certain forms of earth-movement and mountain-building. The geology of this region has been fully described in the Survey memoir on *The Geological Structure of the North-West Highlands*: it is, however, a bulky volume, and the district itself is difficult of access; therefore, to help those who are unable to visit the ground to form a conception of the character and results of the great earth-movements, a model has been prepared of a selected portion. The model embraces an area of about 168 square miles, and is on a scale of 6 inches to 1 mile (vertical and horizontal); examples of it are exhibited in the Museum of Practical Geology, London, and in the Royal Scottish Museum, Edinburgh.

We have now before us a *Guide to the Geological Model of the Assynt Mountains*, by Drs. B. N. Peach & J. Horne, price 1*d*., which will be of the utmost assistance to students in arriving at an understanding of the model and of the great thrust-movements it exemplifies. Some of the place-names will be a little difficult for the southerner; after a struggle with Beinn nan Cnaimhseag or Cnoc na Glas Choille he may long for the military expedient of plain "Hill 60". The pamphlet is illustrated by a sketch-map and a number of sections which greatly assist in the interpretation of the geology. Within thirty odd pages the authors have condensed, with admirable clarity, an immense amount of information; it will be difficult to find a more weighty geological pennyworth.

IV.—Memoirs of the Geological Survey of Scotland.

The Geology of Mid-Strathspey and Strathdearn. Explanation of Sheet 74. By L. W. Hinxman, E. M. Anderson, and others. pp. 97. Edinburgh, 1915; published by Wyman & Sons, Ltd., London, E.C. Price 2*s.* 6*d.* net.

THIS is a continuation of the fine series of Survey memoirs on what is perhaps the most minutely mapped and described region of ancient rocks in the world. The area of 432 square miles dealt with lies almost wholly within the county of Inverness, and most of it is devoted entirely to sport. The country is mountainous and belongs mostly to the dissected plateau of the Highlands, of which the Monadhliath Mountains is a comparatively undissected portion, reaching 3,000 feet in height. To the south-east a part of the great 'monadnock' of the Cairngorm Mountains, with a mean elevation of 3,500 feet, rises out of the plateau surface. Three great river valleys, the Spey, Findhorn, and Nairn, cut across the plateau in a N.N.E. direction, of which the first two are certainly of pre-Devonian age.

The area is entirely underlain by the ancient metamorphic rocks of the Highlands and the igneous intrusions associated with them. Most of the metamorphic rocks belong to one or other of the main groups of the Moine Series, which are classified as pelitic schist and gneiss, siliceous schist and granulite, quartzite, limestone, and calc-silicate rock. These form the lower moorlands of the central and north-eastern parts of the area. Rocks which, owing to rapid alternations of lithological character, cannot be assigned to any of the above groups, and are classed as undifferentiated schists of the Moine Series, occupy the area around the southern granite masses, and form bands across the western and south-western parts of the region. A small area in the neighbourhood of Grantown is occupied by rocks which have a closer lithological affinity with those of the Central Highland or Banffshire Series, and are accordingly separated under the provisional name of the Grantown group. These various metamorphic rocks are fully described under their respective districts.

Igneous rocks which have been involved in the foliation are sparse, and are represented only by thin sills of epidiorite and hornblende schist. The three great granite masses of the Cairngorm Mountains, the Monadhliath Mountains, and Strathdearn belong to the Newer Granite period of intrusion (Old Red Sandstone), and are of post-foliation date. Two or three small bosses appear through the gravels of the Spey valley. The view that all these separate masses are continuous at varying depths beneath the roof of schist is supported by the petrographical identity of the several outcrops, the extensive granitization of the intervening areas of schist, and the behaviour of the outcrops in relation to the form of the ground. It is far more probable, however, that the mass is of batholithic habit, rather than that it is a "large branching laccolite . . . whose irregular upper surface has been partially exposed, at different levels and often over wide areas, by denudation". A garnetiferous augite-diorite, remarkable for parallel intergrowths of garnet, felspar, and augite, forms an unusual variant of the Strathdearn granite. An interesting petrological chapter by Dr. J. S. Flett gives details of the igneous and metamorphic rocks, and describes kyanite-, sillimanite-, and staurolite-gneisses as products of the thermal metamorphism of the schists.

The region can boast of a magnificent range of glacial phenomena, equalling in clearness and beauty those of any other area in the British Isles. The Glacial Period is divided into four stages: the stage of maximum glaciation, in which there was a thick ice-sheet moving eastwardly; the stage of large confluent glaciers originating outside the area; a stage of separation of the confluent glaciers into independent valley glaciers; and finally a stage of high-level corrie glaciers. The retreat phenomena of the valley glaciers are finely displayed in a series of overflow and marginal channels, associated with lateral moraines, high-level marginal terraces, and flat spreads of sand and gravel that occupied the deeper embayments of the ice-margin. The six fine plates are all illustrative of various phases of the glaciation and physiography. Perhaps the best is the frontispiece, showing the great through-valley of the Lairig Ghru, cutting right through the summit plateau of the Cairngorm massif, and fronted by the fluvio-glacial plain of the Rothiemurchus Forest, which, unlike most Highland 'forests', appears to have some trees in it.

G. W. T.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *April* 14, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President referred with regret to the death of the Rev. Alec Field, who was Assistant in the Society's Library and Office from 1900 until 1908. In the latter year he left the Society's service, in order to be trained as a missionary. He was among those lost on the s.s. *Falaba*, torpedoed by a German submarine on the afternoon of Palm Sunday, March 28, 1915. Mr. Field was returning to his post at Bida in Northern Nigeria.

The following communication was read:—

"Further Observations upon the Late Glacial, or Ponder's End, Stage of the Lea Valley." By Samuel Hazzledine Warren, F.G.S. With Notes on the Mollusca by Alfred Santer Kennard, F.G.S., and Bernard Barham Woodward, F.L.S., F.G.S.

The paper is supplementary to that previously published (Q.J.G.S., vol. lxviii, p. 213, 1912), and describes additional sections which increase the range of the deposits. They have now been traced, with the assistance that the author has received from Mr. A. Wrigley, for a distance of $6\frac{1}{2}$ miles along the valley and $2\frac{1}{4}$ miles across it. The section at Hedge Lane, Lower Edmonton, shows several thick, and for the most part undisturbed, Arctic plant-beds, which occur in a deep Drift-filled channel. The relative levels and stratigraphy point to the conclusion that the Hedge Lane deposits belong to a slightly earlier stage of the Low Terrace River Drift than the deposits of Ponder's End. Broadly speaking, they undoubtedly belong to the same group.

The author suggests that it would be a practical convenience if the East Anglian word 'platymore' were adopted for the underlying eroded floor of country rock beneath a later accumulation of Drift. The importance of this 'platymore' surface in the correlation of Drift deposits has been increasingly recognized during recent years, and it seems desirable that it should have a name.

The author supports the correctness of the view that the lower river-terraces are later than the higher river-terraces. Further evidence is also brought forward in support of his view that the Arctic deposits form an integral part of the Low Terrace Drift: that is to say, that they belong to the latest stages in the Pleistocene erosion of the valley, and are not remnants of earlier deposits.

One of the sections described appears to suggest that the climate became nearly as temperate as that of the present day before the mammoth and woolly rhinoceros became extinct.

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2. *April* 28, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President announced the death, on April 16, of Richard Lydekker, who became a Fellow of the Society in 1883, and resigned only on December 16 last. He referred to the value of Mr. Lydekker's contributions to geology, and also to his services to the Society. Mr. Lydekker had been a Member of Council for fifteen years, and a Vice-President for four years.

The following communications were read :—

1. "A Composite Gneiss near Barna in the County of Galway." By Professor Grenville A. J. Cole, F.G.S., M.R.I.A., Director of the Geological Survey of Ireland.

The great mass of granite west of Galway town is seen on its northern margin to be intrusive in a metamorphosed series of Dalradian quartzites, limestones, and mica-schists, and has received a foliation which is parallel with the bedding of this series; this foliation is ascribed by the author to the partial absorption of sheets of the bedded series into its mass. Traces of similar intermingling occur in Townparks (Galway town) and west of Barna. At Furbogh Bridge the granite contains pink crystals of orthoclase, at times 10 cm. long in the direction of the vertical axis, and these have become stranded, as it were, among the foliation planes of dark-green biotite-schist, into which they were carried by an intimate intermingling of the granite, with the schist into which it flowed. Quartz and smaller felspar-crystals from the granite abound in the resulting composite gneiss, and the general effect is comparable with that of igneous intermixtures described from County Down and Skye. In the Galway instance, however, there is no sign of general fusion of the invaded rock, which retains its original foliation and controls the structure of the composite mass.

2. "Further Work on the Igneous Rocks associated with the Carboniferous Limestone of the Bristol District." By Sidney Hugh Reynolds, M.A., Sc.D., F.G.S., Professor of Geology in the University of Bristol.

The paper gives an account of the additional information, concerning the Carboniferous volcanic rocks of North Somerset, which has become available largely through digging trial-holes, since the publication in the Q.J.G.S. for 1904 (vol. lx) of a paper by Professor Lloyd Morgan and the author on the subject. The rocks occur at five localities: (1) Goblin Combe; (2) Uphill; (3) Limeridge Wood, Tickenham; (4) Spring Cove and Milton Hill, Weston-super-Mare; and (5) Woodspring or Middle Hope.

At Goblin Combe, as the result of digging nearly forty trial-holes, it was ascertained that the igneous rocks form two discontinuous, somewhat crescentic masses, each consisting of olivine-basalt overlain by a considerable thickness of calcareous tuff. At Uphill the evidence obtained was insufficient to determine whether the basalt is a sill or a lava-flow. At Limeridge Wood, Tickenham, where only debris of basalt had previously been recorded, the presence of an oval mass measuring about 60 by 25 yards was proved by digging trial-holes, and the fact that it is completely surrounded by limestone indicates its intrusive character. Several additional exposures are described on Milton Hill, where the lava forms a band about 150 feet thick. The lava at Middle Hope or Woodspring is shown to form an irregular and discontinuous mass.

Previous statements as to the essentially basaltic character of these rocks are confirmed. Olivine is present at each locality. Analyses, mainly made by Mr. E. G. Radley, show that in some of the rocks a high percentage of potash is present.

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3. *May* 12, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communication was read:—

"On *Parka decipiens*, Fleming." By George Hickling, D.Sc., F.G.S., and Archibald W. R. Don, B.A., F.G.S.

The paper is a joint statement of originally independent investigations of this Old Red Sandstone organism. The views of Fleming, Hugh Miller, Mantell, Lyell, Powrie, Page, and others are quoted to illustrate the chequered career of this enigmatical fossil in geological literature. To Dawson and Penhallow, supported by Reid and MacNair, belongs the credit of making the first serious attempt to obtain definite evidence as to its nature and of establishing its vegetable character. The present account is based on the observation of great numbers of specimens in the field, and on the microscopic study of impression-material, of thin sections, and of macerated material.

The plant is most abundant in the Lower Old Red of the Kincardine-Forfar-Perth area, where it is by far the commonest fossil, especially in the shale-bands; *Parka* is confined to the lower two-thirds of the Caledonian Series. It is recorded from a few other localities in Central Scotland, and also from the Upper Ludlow and Lower Old Red of the 'Hereford' area.

The organism is shown to be a complete cellular thalloid plant, agreeing generally in its vegetative structure with certain algæ, but differing from all known algæ in the production of cuticularized spores. The thallus is closely set with subcircular swellings ('discs'), each enclosing a mass of simple spores (homosporous). An investing layer, probably one cell thick, of relatively large cells surrounds the smaller-celled 'parenchyma' of the thallus. The spore-masses are individually enclosed by the latter tissue, but there is no indication of a specialized sporangial wall. The growth of the plant is marginal and indefinite, and mature spores are found in plants of all sizes—that is, so far as observed, in all plants that are in a suitable state of preservation. The structure described by previous writers as an 'indusium' is interpreted as the 'sole' of the thallus in a more or less detached condition. While the general structure and mode of growth of the plant make it very difficult to place it higher than the Thallophyta, it must be recognized that the organism is in some respects unique.

II.—Geological Society of Glasgow.

At a meeting on May 13, 1915, Professor J. W. Gregory read a paper by himself and Dr. Horne on "The Annan Red Sandstone Series of Dumfriesshire". He explained the different opinions that had been held at various times with regard to the age of the red rocks of South-Western Scotland. The identification of the age of these rocks and their allocation to their true stratigraphical position had been a matter of difficulty on account of the absence of fossils, with the exception of reptile footprints such as those of Corncockle Moor, and the fact that the rocks occurred in isolated areas. This had led to their all being classed simply as "New Red Sandstones", a loose and unsatisfactory term. It had been found that, in the absence of fossils, a study of the climatic and geographical conditions under which a sedimentary rock had been formed frequently gave useful guidance in identification, and this had proved to be the case in this instance. The rocks of the Annan district can be traced across the border and linked up with the St. Bees Sandstone, which is clearly of Lower Triassic age. The Lochmaben, Dumfries, etc., Sandstones agree rather with the Penrith Sandstone, which is Lower Permian, and exhibit an absence of the Red Shale and angular material which are so prominent in the Annan Series. The Annan Beds seem to have been laid down in lagoons traversed by strong currents, while those of Dumfries, etc., bear every mark of having been formed at a time when the country was covered by one continuous sheet of desert sand, the small grains of pyrolusite and the type of false-bedding being quite characteristic of desert conditions. The only footprints got in the Annan Sandstones, also, are similar to those of the Trias, while those of the Dumfries Beds belong to Permian reptiles.

Mr. Peter Macnair read a paper on "The Hurlet Sequence in North Lanarkshire". He described the succession of strata in the East Kilbride, Carluke, and Strathaven districts, and pointed out that they could be correlated bed by bed with those of the Glasgow basin, with the possible exception of the Hurlet Limestone. He pointed out that the Hurlet Limestone was not so constant as was supposed, and that the Blackbyre ought really to be taken as the datum-line. His co-relation with adjacent areas depended upon the occurrence of the large form of *Productus giganteus* in the Blackbyre, the *Posidonomya corrugata* bed above the Hosie, and the Nielson shell bed above the Blackhall Limestone. He dealt particularly with the section seen at Thorntonhall, and said that he had recently found two Neilson shell beds there.

III.—Zoological Society of London.

March 23, 1915.—R. H. Burne, Esq., M.A., Vice-President, in the Chair.

Mr. R. Lydekker, F.R.S., F.Z.S.,[1] presented a paper entitled "The True Coracoid", in which he stated that the element in birds and post-Triassic reptiles universally known as the coracoid is the homologue of the human coracoid process, and its equivalent the true coracoid of the monotremes and mammal-like reptiles.

CORRESPONDENCE.

CONCERNING 'LATERITE'.

Sir,—The discussion on laterite that arose from a letter of mine published some years[2] ago led to the appearance of a number of very interesting papers in the pages of this Magazine, the latest being Dr. Fermor's account of Professor Lacroix' work in French Guinea. My own views on laterite were, I think, made sufficiently clear in the discussion referred to, and I would not trouble you further were it not for a point connected with Dr. Fermor's last paper.

I have been engaged in the study of tropical weathering products for some time and find that one of the difficulties is *to prove*, when dealing with very fine-grained products, the presence of aluminium hydrates mixed with hydrous aluminium silicate. On p. 127 of the current volume of the Magazine Dr. Fermor mentions Mr. Edward's paper in *Economic Geology* (ix, pp, 112–21, 1914) on the occurrence of aluminium hydrates in clays, and after saying that the author examined a large series of *analyses of clays*, adds: "The percentage of bauxite thus detected in these clays." But no bauxite was detected. What Mr. Edwards did was to assume that even if

[1] This was the last paper communicated by the author, who died on April 16, 1915. See Obituary, Geological Magazine, May, p. 238.

[2] Dated July 4, 1909 (see Geol. Mag., 1909, p. 431).

a mixture of hydrous silicates of alumina were present in a clay, the resultant composition would be that of kaolinite, and to recalculate as bauxite from a number of analyses, with the help of a mineralogical slide-rule, the excess of alumina over that required for kaolinite. The objections to this procedure were so clear that I was surprised to read Professor Ries' detailed criticism in the June number of the same periodical.

Whatever one may think about laterite, whether the setting property is an essential characteristic or not, whether the word would exist but for that property or not, it is now clear that under the heading 'laterite' petrologists have taken up the study of hydrates of alumina as weathering products. I think the relationship is unfortunate, as may have been gathered previously, and that the main objection to Dr. Fermor's classification of laterites and clays (Geol. Mag., 1911, p. 514), apart from the two new terms, is the necessity of long and difficult chemical analyses in place of determining the 'setting' property of laterite or plasticity of clay.

I need not dwell on the dangers of mineral recalculations in very fine-grained rocks where attempts at identification of component minerals only reach what a distinguished petrologist, under whom I once worked, called 'pious opinions', nor need I recall the dangers of assuming clays to be composed of kaolin. Mr. Hutchings' work in the 1894 volume of this Magazine will be remembered by most of those interested in the subject, and Professor Ries deals with the matter in his *Clays, their Occurrence, Properties, and Uses* (pp. 40 et seq.). In dealing with weathering products recalculation from a total analysis will not do, and the best method I have arrived at yet is fractional treatment with acids and alkali solution. The idea is simple. Alumina may be present in a weathering product as silicate or hydrate, or perhaps as colloid alumina, in a soluble form (kaolinite yields to prolonged acid treatment). If it is there as a silicate, gelatinous silica will be liberated and perhaps go partly into solution. Experiment with silica derived from powdered wollastonite by acid treatment shows that a rapid wash with hot 10 per cent KHO (say for 15 seconds) should take up all liberated silica without attacking other minerals in the rock to a serious extent. If no silica, or very little, is found in the KHO solution or the acid solution, then it is a fair presumption that the alumina dissolved was not there as a silicate or that there is only a slight admixture of silicate. Successive acid attacks should give approximately the amount of soluble hydrate (or colloid alumina) present. Will anyone tell me of a better method for mixtures of hydrous silicates and hydrates where only chemical analysis can be employed?

My impression so far is that aluminium hydrates are formed here in small quantities wherever aluminium silicates exist, and that kaolinite is decomposed to a certain extent. I have examined kaolinized felspar crystals in this connexion, the kaolin being a product of weathering, and believe them to contain some hydrate. One chemist confirms my results. Another contradicts them.

A point of some interest to me has cropped up lately in connexion with the discussion about laterite in this Magazine. Dr. Evans said that to the best of his recollection he never heard the term laterite applied by engineers in Southern India to anything but the weathering products characterized by aluminium hydrates, etc. Last year a geologist visited me who had spent some years in India. As we were motoring one day he asked me what rock a certain road-metal was. "That," I said, "is what we venture to call laterite." "But," he replied, after examining it, "it is almost identical with the Indian laterite I know." So perhaps we are not such sinners in Malaya after all.

J. B. SCRIVENOR.

BATU GAJAH,
FEDERATED MALAY STATES.
April 15, 1915.

OBITUARY.

FORTESCUE WILLIAM MILLETT.

BORN 1833. DIED FEBRUARY 8, 1915.

MR. F. W. MILLETT, chiefly known to geologists for his work on the Foraminifera of the St. Erth Clays, was a man of few friends, in whom he confided as an active worker on the more recent forms. His main results were a series of papers on the Foraminifera of the Malay Archipelago (Journ. Roy. Micro. Soc., 1898–1905) and on the Galway shores in conjunction with Mr. F. P. Balkwill (Journ. Micro. & Nat. Sci., iii, 1884). Millett was a great linguist, was deeply versed in the West of England dialects, and was a remarkably well-informed man. But he was a recluse, made few friends beyond his local circle, and was but rarely seen in London of late years. He had a wide and thorough knowledge of his special subject and its literature, but publication was a labour, and much of the work he did died with him. He was 82. C. D. S.

MISCELLANEOUS.

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[1] See Walter Keeping and C. S. Middlemiss, "Railway Sections at Cave, Yorkshire": GEOL. MAG., 1883, pp. 215–21.

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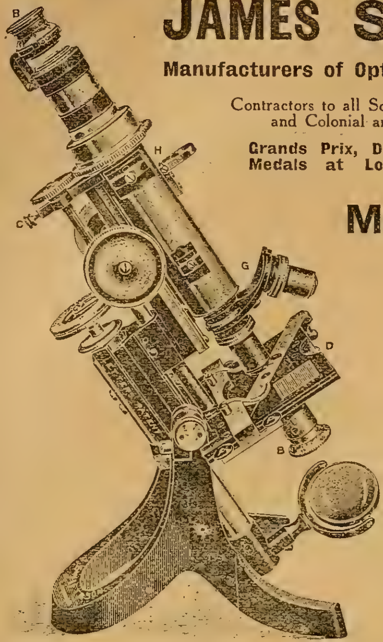

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ORIGINAL ARTICLES.

I.—The Geological Age of the Carrara Marbles.

By Professor T. G. Bonney, Sc.D., F.R.S., and the Rev. H. H. Winwood, M.A., F.G.S.

THE statuary marbles of Carrara have been repeatedly asserted to be metamorphic limestones of earlier Mesozoic or later Palæozoic age. Similar statements were once frequent in regard to other mountain regions, but they have one by one dropped out of geological literature. This, however, is such a hardy perennial as to be still repeated in petrological and other textbooks.[1] Doubts, however, were felt by the first author in 1878, and these became almost certainties after 1886, but as each visit was only for a few hours,[2] and did not allow of a proper examination of the rocks in situ, he deferred writing on the subject till he could spend a longer time at Carrara. That opportunity, however, never came, and is not now likely to occur; but on finding not long since that his friends, Professor Boyd Dawkins and the Rev. H. H. Winwood, had visited the quarries in 1898, and the latter had published an account of the district, with a sketch-section drawn by the former,[3] he communicated with them, and the following paper summarizes the experience of the three, which it is hoped may help in laying another metamorphic ghost.[4]

[1] See, for example, *Text-book of Petrology*, vol. ii, Sedimentary, F. H. Hatch and R. H. Rastall, 1913, p. 250. In books of earlier date the marbles are said to be Lower Jurassic, *Building and Ornamental Stones*, E. Hull, 1872, p. 127; Triassic, *Traité de Géologie*, A. de Lapparent, 1906, p. 1100; Upper Triassic on the *Carta Geologica della Liguria*, by A. Issel and S. Squinabol (1891), and they are associated with micaceous schists in a short text published with the map. They are assigned to the same age in a description of an excursion to Carrara, *Bollettino della società Geologica Italiana*, vol. xxi, p. 163, 1902, which classes some underlying schists and marbles as Permo-Carboniferous, and some schists beneath those as indeterminate Palæozoic, and gives the following succession of the overlying beds, from the base of the Miocene sandstones and conglomerates: Eocene, sandy and calcareous strata; Upper Cretaceous, varied deposits; Lower Cretaceous, limestones; Tithonian, Lias and Rhætic, various; all these being more or less fossiliferous. W. P. Jervis, however, *I Tresori sotteranei dell'Italia*, vol. iv, p: 261, 1889, regards the marbles as pre-Palæozoic. A summary of Italian opinion prior to 1878 is given in this Magazine by Professor G. A. Lebour (1878, pp. 289 and 382). He adopts Coquand's verdict for a Carboniferous age.

[2] Unfavourable weather made both shorter than had been intended.

[3] Proceedings of the Cotteswold Naturalists' Field Club, vol. xiii, p. 57.

[4] For the paragraph marked thus § Mr. Winwood is mainly responsible; for those marked thus ¶ Professor Bonney.

§ The Carrara Mountains, also called the Apuan Alps, are a short range of bold peaks rising abruptly from the Apennines to a height of some 6,000 feet above sea-level, in striking contrast with the tamer scenery of the coastal zone. Their steeper slopes are deeply gashed by valleys and carved into spurs, on one of which, between the Maira and the Serchio, lie the noted quarries of Carrara and Massa. These, with others in the district, are high up on the mountain side; the slopes of white debris at a distance resembling snow, and increasing the likeness to an outlier of the Alps. Mr. Winwood, with Professor Boyd Dawkins, began by visiting quarries, of which one furnishes the ordinary clear white Carrara marble, called *Marmo Siciliano*,[1] used in architecture and for common statuary, and the other a kind still better adapted for the latter purpose, which also has been employed in Trajan's Column and the Pantheon at Rome.[2] From these they passed on to quarries in the Piastra Valley, which supply the *Marmo Statuario*, the use of which is signified by the name, and then to others (at a lower level) which yield the *Marmo Bardiglio*, bluish in colour, and sometimes varied by dark veins. On the following day they went to quarries in glens leading down to the Bedizzano Valley, of which some had been worked by the Romans. These also furnish good white marble; the highest point reached, a quarry at La Gioija, being at an altitude of about 1,900 feet. In descending to the Colonata Valley, they obtained a good continuous section of the rocks (in ascending order) which is represented in the annexed diagram, copied from a rough sketch by Professor Boyd Dawkins, the basal line running from about 624 feet to 1,400 feet above the sea.

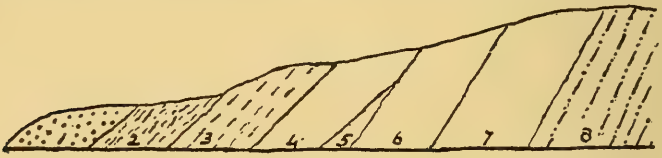


FIG. 1.—Diagram of Strata in Colonata Valley.

1. Conglomerate (Recent). 2. Crushed Sericite Schist. 3. Micaceous Schist (Bedizzano Valley). 4. Veined Sicilian Marble (910 feet). 5. Pavonazzo Marble. 6. Bardiglio Marble (Torone 1,241 feet). 7. Sicilian Marble. 8. Schist (Colonata Valley).

On this section Mr. Winwood remarks that the beds apparently dip at a high angle (in some instances they are nearly vertical), but that it was sometimes difficult to ascertain whether this was true dip or cleavage. In one quarry (Ravaccione) the signs of crushing are very marked; these could be seen in other places, as well as signs of faulting, but the intercalation of the marble in the schists appeared to be indubitable.

[1] So called, I have been informed, because at one time it was conveyed to Sicily and exported thence to other places.—T. G. B.

[2] There are other quarries of different varieties of marble, one important group being near Seravezza, to the south-east of Carrara and Massa. See *Vasari on Technique*, edited by G. B. Brown, 1907, pp. 45–8 and 119–26.

¶ On Professor Bonney's first visit he did little more than examine the quarried rocks and fragments, more or less water-worn, brought down by the stream which debouches near the town of Carrara. On his second visit he walked for some distance up the valley, collecting specimens of the micaceous schists, often gneissic in aspect, which were fairly common. All of these showed signs of crushing while in a crystalline condition, and some a conspicuous cleavage-foliation. He failed, however, to find any specimens of a marble with lines of mica and chlorite (?) which he had seen built into the walls of the Croce di Malta Hotel at Spezzia, or any marked signs of mechanical disturbance in the pebbles of ordinary marble, most of which were pure white, but some showed a lead-coloured clouding or streaking. He then ascended to Miseglia, on the right bank of the valley, without finding any good sections *en route*, owing to overgrowth, but ascertained, especially in a quarry near this village, that an ordinary dark limestone, with indications of mechanical disturbance (resembling some near Spezzia and others of Jurassic age in the Oberland Alps), which was associated with lighter-coloured varieties, occurred in close proximity to normal Carrara marble.

¶ On this occasion he collected a few representative specimens of the gneissose and schistose rocks, and one of the former had been given to him, about 1885, by the late Professor Carvill Lewis.[1] This specimen, labelled by the donor "sericite-schist, Upper Triassic, Carrara", has a gneissose aspect, and is obviously much crushed, the curving cleavage surfaces glimmering as usual with a minute silvery mica.[2] A transverse section exhibits zigzagging bands of two principal constituents, the less abundant almost black, the other nearly white. The latter, though sometimes rather like felspar, proves on examination to be really quartz. The microscope shows that this mineral forms rather polygonal grains, varying in size from about one-fiftieth of an inch down to mere specks. The larger grains often occur in small groups which are suggestive of broken-up veins. The quartz is associated with an almost colourless mica. A few of the flakes are about ·01 in. long, having a faint brownish tinge, and giving bright colours with crossing nicols, but the majority vary on either side of ·002 in. in length. These, I suspect, are produced by the shearing of larger flakes. The dark mineral mentioned above often occurs in more or less clustered granules, which so far as they have a definite shape are slightly prismatic. They show a metallic lustre with

[1] I think he gave it to me shortly before my visit in the autumn of 1886, remarking at the time: "Here is a gneiss of Triassic age from near Carrara." My reply was to this effect: "If you had told me you got the specimen not far from the St. Gotthard, on the northern side of the Val Bedretto, I should not have been surprised. Was there in the field an actual sequence from it to indubitable Triassic rock?" "Not exactly," he answered, "but they were exposed on opposite sides of a valley." "Well, then," said I, "a fault may have gone down that valley, so, though greatly obliged to you for the specimen, I cannot admit that it has been proved to belong to the Triassic system."—T. G. B.

[2] See Presidential Address to the Geological Society, Quart. Journ., vol. xlii, Proc., p. 65, 1886. See also id., vol. xlvi, pp. 202–4, 1890, and other papers of mine on Alpine schists.—T. G. B.

reflected light, their colour being more of a very dark brown than black, but they give a black streak, with a faint undertint of blood-red, so I expect they are really magnetite with slightly oxidized surfaces. Kyanite, if I rightly identify it, is present in rather elongated prisms, also a few minute prisms of a slightly bluish-green mineral, with a high refractive index and a straight extinction, which is almost certainly tourmaline, and a small, rather acicular, brownish mineral, not unlike rutile.[1] Thus the rock is a quartz-mica schist rather than a gneiss, and has evidently undergone some shearing, though the quartzes do not show strain shadows.

¶ Of five specimens (collected as generally representative) from the stream bed above Carrara and below Miseglia, one has the aspect of a much crushed gneiss, with a rude but distinct cleavage. In colour it is whitish, with lead-coloured spots, and on its external flattened surfaces are 'smears' of a similar coloured mica. Microscopic examination shows the rock to consist of quartz, in grains often slightly elongated, from about ·02 in. to ·001 in. in diameter; the larger often having ragged edges. Flakes of an almost colourless mica, giving bright polarization tints, occur between the grains, especially the larger, their length being from about ·006 in. downwards. Granules of an iron oxide, similar to that in the last specimen, occur singly and in 'coveys' with three or four rounded or quadrangular grains of tourmaline, varying in colour from brownish to blue; also one or two of apatite, and the above-mentioned brownish microliths. A second specimen, which it seemed needless to slice, is on the whole intermediate between the two now described, but the crush surfaces are more irregular than in the former, and the rock is more 'mottled' in texture, being traversed by patches of the lead-coloured mica, which has a very silvery lustre.

A third specimen, evidently crushed, for it exhibits a very rude cleavage, is rather white in colour, and resembles a fine-grained, quartzose gneiss, with a fair amount of silvery mica. But microscopic examination does not reveal any felspar, though the former presence of that mineral may possibly be suggested by a clear grain, containing here and there numerous minute specks suggestive of an aluminous residue, and seemingly having a slightly higher refractive index than an adjacent grain indubitably quartz. The mica resembles that already described, exhibiting a distinct foliation, but not very obvious signs of crushing.

¶ The specimens described above present a general resemblance, especially under the microscope[2] to the quartz-schists, which not infrequently occur in the Alps. My collection contains specimens obtained at intervals from the south side of the Great St. Bernard to the west one of the Gross Glockner. They are well developed in the Einfischthal, especially near Vissoie and around Zinal, where they not unfrequently contain pebbles, and about Saas Fee, where they

[1] Mr. R. H. Rastall, who has had considerable experience in examining microlithic minerals, informs me that the colouring matter appears to him mainly external and suggests brookite as a possible identification.

[2] It shows the gneissose aspect to be illusory, the apparent felspar granules being due to pulverization of the quartz.

sometimes include bands of mica from fully one-third of an inch in thickness down to mere streaks. They also occur on the south side of the Gorner Grat, near Pianura di Segno on the Lukmanier Road, to the south of Splügen village, and in the upper part of the Averserthal, associated with dark mica schists and calc-mica schists which pass into white marbles. So far as I have seen, these quartz schists generally occur low down in this group of the Upper Schists.[1] They also have some resemblance to a quartz schist from a hill north of the west end of Derrylea Lough, Connemara,[2] to one from Morone in the Braemar district (though this rock shows less signs of crushing), and still more to another one nearer that health resort. These quartz schists present some resemblance to the highly crushed basal Cambrian quartzite of Glendhu (Sutherland), in which, however, any argillaceous constituent is less altered, and to crushed Torridonian near Kinlochewe and Loch Clair, in which also mica is not so well developed, fragmental felspar still remaining.

¶ A fourth specimen from the same valley is a schist with much mica, slightly brown or greenish in tint, and quartz; both small, the latter slightly the more abundant, and the former showing sharp waves or loops, with roughly parallel axes, as if a little more flexure would have produced a strain-slip cleavage. Under a quarter-inch objective, the quartzes are seen to be slightly elongated and the mica almost colourless, but interspersed with it are rather numerous pale umber-brown granules, slightly prismatic in form (? minute staurolites) and a few which are opaque, probably an iron oxide. Three or four prismatic grains, greenish-blue in colour and pleochroic, are probably tourmaline. A fifth and smaller specimen so much resembles this one that it has not been sliced. I have obtained rocks similar to these from more than one part of the Alps where pressure has produced conspicuous effects; occasionally from that 'waiting room' named Casanna Schiefer, but more often from the Upper Schists. For instance, they much resemble a specimen obtained between Mittersill and Kitzbühel on the southern side of the pass near the top.

¶ I have examined only a few slices of Carrara marble, because I could not collect my specimens in situ. Those of the best marble are granular in structure, consisting of crystalline calcite with a variable amount of dolomite, showing some pressure twinning but no signs of crushing; one of them containing two or three tiny fairly idiomorphic quartz crystals. A specimen labelled "brecciated marble, Seravassa"[3] is a crystalline dolomite.[4] It consists of pieces or bands of coarser texture in a finer-grained matrix. The Carrara marble is very similar to that from Pentelicus,[5] which, however,

[1] Quart. Journ. Geol. Soc., vol. xlv, p. 95, 1889.

[2] Perhaps also to the quartz-rock of the Twelve Pins, which I have not actually visited.

[3] For which and other interesting specimens of marbles I have to thank Mr. W. Brindley, of Westminster.

[4] In the Binn Valley crystalline dolomites are interbedded with dark mica schists.

[5] This is asserted to be Cretaceous (Hatch and Rastall, *ut supra*, p. 250). I have seen a little of this neighbourhood and am unable to accept the identification.

affords a rather more distinct indication of pressure, as does the well-known Cipollino from Eubœa, which, of course, contains more pale-green mica, etc. It is also nearly identical with the white marbles here and there intercalated in the above-named dark mica schists, the isolated masses of marble on both sides of the Tosa about Ornavasso, and those seemingly intercalated in gneiss on the Splügen Pass, and on the descent from the San Bernardino Pass to the baths of the same name.[1] But all of these afford distinct indications of some amount of crushing. They differ much from the dolomites of the South-Eastern Tyrol and from some rather marble-like limestones in other parts of the Alps, both of Mesozoic age; even from the remarkable imitation, but imitation only, of Cipollino marble worked near Saillon in the Rhone valley not far from Saxon.

¶ The absence of signs of crushing in the best Carrara marble, while it is so marked in the schists, is certainly a difficulty, but we must suppose, and I have little doubt that a fuller study of the sections in the field would show it to be the case, that the statuary marble is obtained from lenticular masses which have been saved from being crushed by the yielding of adjacent bands. I have noticed something of this kind in one or two of the Alpine marbles.

Thus the evidence obtained in the field and from a study under the microscope of the schists and marbles of Carrara is altogether adverse to the hypothesis of a Mesozoic, or even later Palæozoic, age. That, as with similar rocks in the Alps, is most probably Archæan. The region is one where the rocks have been much faulted, but in which those indubitably Mesozoic retain their usual aspect and character; as is their habit, so far as I have seen, in districts such as the Alps, where pressure-metamorphism has produced notable effects.

II.—On the Formation of the River Tyne Drainage Area.

By Edward Merrick, M.Sc.

THE object of this essay is to outline the connexion between earth-movements and the formation of the River Tyne drainage area; the period of its formation is also alluded to, though it is less definable. This object becomes more accessible on dividing the area into the following parts and considering each separately:—

A. The Main Valley of the Tyne.
B. The Watersheds South of the Main Valley.
C. The Watersheds North of the Main Valley.
D. The Earth-movements considered stratigraphically.
E. The Relationship to other Drainage Areas.

A. The Main Valley of the Tyne.

The rocks forming the drainage area of the River Tyne are all Palæozoic, and except for a small inlier of Silurian deposits at the

[1] After careful examination I formed the opinion that the apparent inter-bedding was illusory, and that they were nipped in by thrust faults. Where, however, the marble was associated with the calc-mica schists it obviously graduated into these.

head of the Redewater they are all members of the younger Palæozoic period, the youngest member of which, the Permian, covers but a very small area on the East Coast. Up to the present no later deposits, except the Glacial and post-Glacial deposits, have been discovered in this area.

In other parts of England—the Kent Coal-field, the Bristol Coal-field, the Cotteswolds, and the Staffordshire Coal-field—the Mesozoic deposits rest unconformably upon a junction-plane of Palæozoic rocks, the Trias being frequently the first unconformable deposit upon it.

In South Durham there is no exposure of the junction of the Permian and Triassic rocks, and there is some conflict of opinion as to where the divisional line is to be drawn in some borings passing through them. Still, for practical purposes, the Tyne area may well be regarded as a continuation of this junction-plane which has been eroded into the present system of hills and valleys. Placing the formation of this junction-plane, peneplain, or surface of planation—whatever the causes were which produced it—as originating about this time, it follows that it was probably affected by the later movements proved in adjacent areas, and that such movements were liable to follow the same general trend and lines of weakness as the pre-Permian movements. Something of this kind must have taken place, for when walking westwards along the left or north bank of the River Tyne it is noticed that the surface-levels of the country to the north are typically lower than on the south or right bank, and that this difference continues to increase on walking westwards. In other words, the Durham side of the river has higher contours than the Northumberland side.

The following Table of Levels, taken from the 1 inch Ordnance Survey Maps, illustrates this difference. The most easterly stations are at the head of the list:—

TABLE I.

LAND LEVELS IN FEET.

Left Bank.	Height.	Difference.	Height.	Right Bank.
Tynemouth[1]	120	*157*	277	Cleadon.
Moorhouses	242	*65*	307	Down Hill.
Scaffold Hill	253	*3*	250	No hill, but rising ground.
Byker Hill[1]	214	*286*	500+	Beacon Lough.
Condercum	409	*290*	700	Tinkler Row.
Westerhope[1]	435	*314*	749	Near west of Sandy Gate.
Heddon Laws	501	*84*	585	High Spen.
,, ,,	,,	*404*	905	Billingside.
,, ,,[1]	,,	*534*	1,035	Pontop Pike.
Harlow Hill	554	*296*	851	West of Currock Fell.
,, ,,	,,	*76*	620	Near Edgwell House.
Kip Hill	649	*311*	960	Kilnpit Hill.
,, ,,	,,	*264*	913	No name.
,, ,,[1]	,,	*582*	1,231	Stoterley Hill.
Little Whittingham	689	*571*	1,260	Edmundbyers Common.
,, ,,	,,	*343*	1,032	Pit House Fell.

[1] Picking out the five marked hills as least denuded.

TABLE II.

Tynemouth	157	feet lower than the hills on the right bank.
Byker Hill	286	
Westerhope	314	
Heddon Laws	534	
Kip Hill	582	

The second table clearly brings out the steady increase of difference in surface levels on walking westwards, which is quite evident, as both watersheds are near together. However, on nearing and passing Hexham, it is not so easy to make a table as above, because the chief eminences of the watersheds are widely separated. The southern watershed of the River South Tyne is very much higher than the watershed between the North and South Tyne, by about 1,000 feet; a still greater difference in levels than at Kip Hill. Between these two watersheds lies a wide synclinal hollow, the main valley of the Tyne. Bearing this difference of levels in mind, the thought arises that it may have been caused by a fault running from east to west, with its downthrow on the north, the magnitude of the downthrow also increasing from east to west.

Consider now what the effects of such faulting of the junction-plane would be besides producing this difference in levels. (See Fig. 1.)

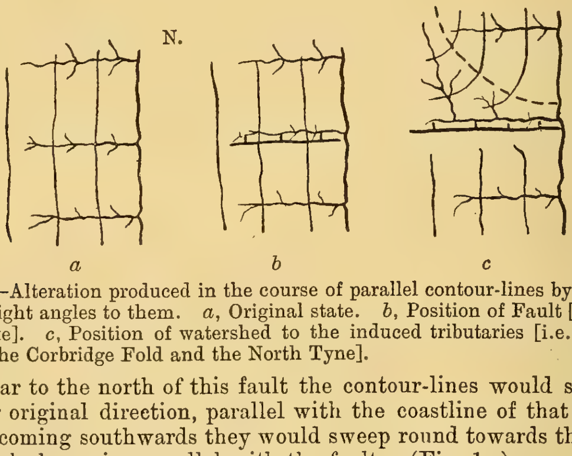


FIG. 1.—Alteration produced in the course of parallel contour-lines by faulting at right angles to them. *a*, Original state. *b*, Position of Fault [Stublick Dyke]. *c*, Position of watershed to the induced tributaries [i.e. position of the Corbridge Fold and the North Tyne].

1. Far to the north of this fault the contour-lines would still run in their original direction, parallel with the coastline of that period, but on coming southwards they would sweep round towards the west, ultimately becoming parallel with the fault. (Fig. 1*c*.)

2. The alteration in the direction of the contour-lines and slope of the country would be accompanied by a change in the river drainage on the north of the fault, for tributaries would come from the north and north-west, increasing in length where the throw of the fault was greater.

3. A watershed running in a general north-westerly direction from the fault would be produced to the north-east of these induced tributaries. (Fig. 1*c*.)

4. Faulting to such an extent as this could not take place without affecting the lie of the solid rocks.

5. It would result in bringing younger rocks against increasingly older ones on passing from east to west. (Fig. 2.)

6. The *strike* of the rocks would follow the general trend of the contour-lines as already described.

7. Where the throw of the fault was small, the alteration in direction of the lines of strike and contour-lines would also be small, and they would still resemble ancient shore-lines through being nearly concurrent with those in process of formation.

8. The course of the main river would be concurrent with that of the fault. (Fig. 1*c*.)

The next step is to examine the surface and geological features of the area to see if such disturbances and results have taken place. Taking each of the above considerations in turn, it is found that—

1. If the valleys of the Tyne area be imagined as being filled up as high as the original surface of the junction-plane, the contour-lines do then change their direction as mentioned. This reconstruction of the surface contours can be done on the 1 inch contoured map by joining the most easterly and southerly occurrences of the same contour heights together by a line bounding them from the area on which that height does not occur.

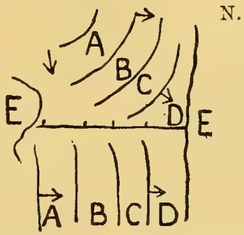


Fig. 2.—Diagram of the strike in the strata in the same area as Fig. 1*c*. E = Later deposits. D = Permian. C, B, A = Carboniferous.

2. The North Tyne and its tributaries are seen to flow in a direction consistent with the above reconstruction.

3. A watershed does run in this direction, which is the same as that of the Corbridge Fold originally described by Professor Lebour.

4. The lie of the rocks and the heights at which they outcrop are changed. The Corbridge Fold and the extension of the Coal-measures (with a southerly dip) along the Tyne valley are partial results of this faulting.

5. The Ninety Fathom Dyke, which runs generally east and west, throws the Magnesian Limestone and Yellow Sands of the Permian against the Coal-measures, and younger Coal-measures against older Coal-measures, at its eastern exposure. Further inland the Stublick Dyke commences, which brings the Coal-measures successively against the Millstone Grit, Carboniferous Limestones, and Shales on proceeding westwards. At the extreme west this junction-plane has been lowered to such an extent that Triassic rocks were deposited upon it. It must be pointed out, however, that at Cullercoats the present land levels are the same on both sides of the Ninety Fathom Dyke, yet

near Tynemouth the two banks of the Tyne are at different levels, as already shown in the above table. This would seem to indicate by its influence on the Tyne banks that the Heworth 25 fathom dyke, rather than the Ninety Fathom Dyke, is to be considered as the easterly continuation of the Stublick Dyke, for it extends the difference in levels produced by that dyke. This would also indicate that the Ninety Fathom Dyke is the oldest of the three faults.

6. The general *strike* of the strata does follow that of the restored contour-lines.

7. The restored contour-lines, up to 300 feet in the eastern area, are fairly concurrent and in general trend follow that of the present-day coastline.

8. The main valley of the Tyne is concurrent with the Stublick and Heworth dykes, and is therefore very straight.

If a line be drawn on the north bank of the river from Fourstones Railway Station to the Coastguard Station at Tynemouth, then the river lies wholly to the south of it; similarly, the river lies wholly to the north of a line drawn on its south bank from Stocksfield to Heworth Shore. On drawing a line half-way between these two boundary-lines, the mean course of the existing river is obtained. From this line the windings of the river are measured in the following table, the easterly stations being at the head of the list:—

TABLE III.

Locality.	Deviation or Winding.	
Tynemouth . . .	1·8 miles	north
Heworth Shore . . .	1·9 ,,	south
Team Mouth . . .	1·775 ,,	,,
Stocksfield . . .	2·125 ,,	,,
Fourstones Station . .	2·275 ,,	north
Maximum winding .	4·4 miles in all.	

The north and south bounding-lines diverge westwards and are cut off by the Pennine Fault and Triassic deposits.

It is rather peculiar that Condercum—409 feet—lies near the mean course of the river, and that there is no land north of it which reaches this height. Byker Hill is also in a similar position. Condercum is on the south or upcast side of the Ninety Fathom Dyke, and stands upon sandstone, of which material Byker Hill is also composed. The strata dip gently from these two hills towards the present position of the river. Denudation beginning in the softer materials above this sandstone has worked southwards and cut downwards till the present river valley was formed, leaving these hills as monuments of the former height of the land. It is not necessary to conclude that these hill-tops were actually the bed of the river in times past, for the mean course of the river is drawn, not from the past, but from the present windings of the Tyne.

B. The Watersheds South of the Main Valley.

On going along the foot of the Cross Fell escarpment from north to south, the solid rocks are seen to have been faulted down to the west, while those on the east or upcast side have been bent into an anticlinal arch. Consider what the effect of this combined movement would be *supposing* some or all of it to have taken place after the formation of this junction-plane. (Fig. 3.)

Effects of the anticline on the east of the Pennine Fault:—

1. Near the fault there would be a system of nearly parallel contours on each side of the axis; owing to the general easterly slope of the country these contours would meet by wrapping round Cross Fell as a centre, giving it the appearance of a half dome.

2. A somewhat radiating system of streams and watersheds with an easterly trend would originate from this half dome and the long axis of the anticline.

3. The synclines on each side of the long axis would be the lowest ground in the neighbourhood, and water would therefore drain into them and newer deposits would be liable to form in these areas.

4. The Stublick Dyke would now lie in the northern syncline.

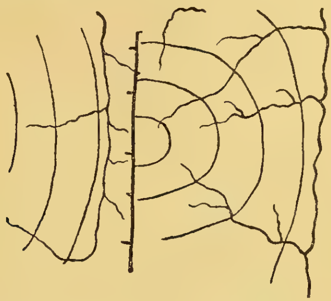


FIG. 3.—Diagram of contour-lines and river courses on both sides of a fault cutting a peneplain buckled into an anticline [i.e. the Pennine Fault and the Cross Fell Anticline].

Effects of the anticline west of the Fault:—

5. If the long axis of the Cross Fell anticline still dipped to the east, i.e. rose to the west, the contours of this junction-plane would partially encircle the mountains of the Lake District; those contours near the escarpment foot would, however, be straighter than those on the top.

6. There would be a tendency for a river or a watershed to form above the long axis of the anticline (at right angles to the Pennine Fault), depending upon whether the slope of the long axis was steeper or not than the slope of the limbs of the anticline.

Effects of the Pennine Fault:—

7. The land surface being lowered on the west would produce a repetition of the contour-lines occurring on the east of the fault.

8. The throw of the fault would be measured by the displacement of the contours. (Fig. 4.)

9. A north and south watershed would be produced along the top of the escarpment face.

10. A fairly straight stream flowing generally parallel with the fault would form at the foot of the escarpment.

11. This stream would be fed by streams from the fault escarpment and collect tributaries from the west and south-west.

12. The area near the fault would be liable to be covered by younger deposits.

Taking each of the above considerations in turn and examining the surface and geological features of the area, it is found that—

1. The contour-lines of the restored surface run in an elliptical shape round Cross Fell as a centre.

2. The South Tyne, Wear, and Tees radiate from Cross Fell, while the long axis of the anticline acts as the watershed between the Tyne and tributaries to the Wear and Tees.

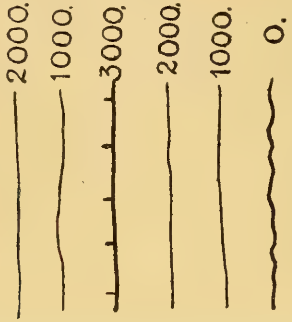


FIG. 4.—Land levels repeated by faulting parallel with the contours [i.e. Pennine Fault and escarpment face].

3. The main valley of the Tyne lies in the northern syncline, and that of the Tees in the southern, in which Triassic rocks are present.

4. The Stublick Dyke is in this position.

5. The contour-lines do run in this general direction near the mountains, but they are covered over near the Pennine Fault.

6. The River Eamont, which flows through Lake Ullswater and onwards till it joins the River Eden near Culgaith, occupies the position of this inferred anticlinal axis.

7. The contours are repeated, but those near the Fault are out of reach.

8. Regarding the Fault in this light, and subtracting the thickness of the Mesozoic rocks from the present-day land levels, then subtracting this level from the height of Cross Fell, an approximate value for the throw of the Pennine Fault during post-Palæozoic times is obtained.

9. There is a watershed in this direction.

10. The River Eden occupies this position.

11. Tributaries are received from these directions.

12. The Trias is present in this area. (Fig. 5.)

The general direction and slope of the southern watershed are from Cross Fell (2,930 feet), to Cleadon (277 feet), which is 48 miles away.

If this watershed were a peneplain, then, by drawing a sloping line between these two heights, the levels that the hills in between should reach can be marked off along it. When this is done it is found that the actual heights of the hills are below their calculated ones, and that on leaving Cross Fell the difference increases, then decreases on nearing Cleadon; the greatest difference being half-way between the two places, where instead of the land level being at 1,500 feet, it is 1,000 feet, thus indicating that a slight bending, a sagging of 500 feet, has taken place. (Fig. 6.) The tendency of this bending is to space the contour-lines nearer together in the west and further apart in the east, till near Cleadon, when they come

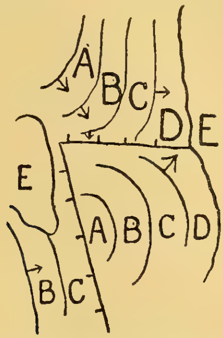


Fig. 5.—Diagram of the strike of the strata in the same areas as in Figs. 2 and 3. E, D, Later deposits. C, B, A, Carboniferous.

closer together. The tributaries from this watershed are naturally influenced by this bending. The change in position of the contours influences the direction in which the streams flow.

The Rivers South Tyne, West and East Allen, and the Devil's Water all run nearly at right angles from the watershed, but owing to the bending the River Derwent runs along a slanting course into

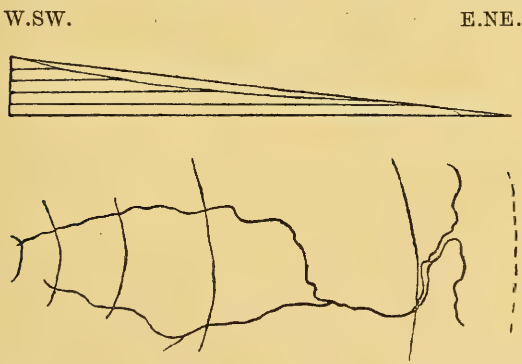


Fig. 6.—Slight sagging of a peneplain causing different spacing of contours [compare with the Wear drainage area].

the Tyne Valley. The lessening of the slope by the wider spacing of the contours gives the streams greater liberty for forming a meandering course. Had this bending increased beyond a certain amount, a ridge or dome would have been formed near the coast, and the contours would have wound round it instead of around Cross Fell;

this would also have caused the meandering streams on the flat area to turn either to the south or north, so as to pass round it to the sea. (Fig. 7.)

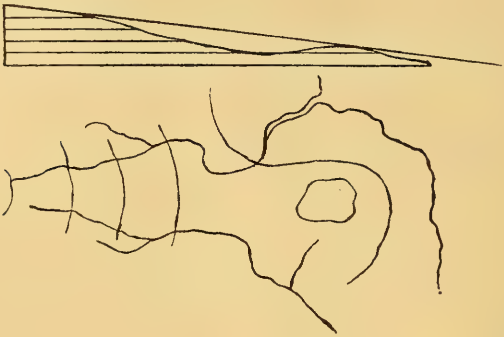


FIG. 7.—Decided sagging of a peneplain causing a coastal dome or range of hills [compare with the Tees drainage area].

Are the changes in direction of the Rivers Tees and Swale produced by such bending, and did the Cleveland Hills originate this way?

C. THE WATERSHEDS NORTH OF THE MAIN VALLEY.

The watersheds on this side of the River Tyne may be considered as forming four districts—

1. That from the coast to near Corbridge has a watershed nearly parallel with the Tyne and is an example of the drainage of a gently sloping plane.

This district gives no important tributaries to the river. The largest one is the Ouseburn, whose chief collecting-ground is to the north of the Ninety Fathom Dyke, which drains this area towards itself, the Ouseburn cutting across the line of fault in the region of its greatest amount of throw.

2. The alteration in direction of the watershed from Corbridge towards Bellingham has already been described in the section on the Main Valley of the Tyne.

3. The Rivers North Tyne and Reed form another district consisting chiefly of a main watershed on the Cheviots, running from Blackhall Hill to Caplestone Fell, from which a parallel system of streams and watersheds runs at right angles. A confluence of the streams takes place before the united river crosses the outcrop of the Great Whin Sill. This great mass of whin causes escarpment lakes on the north of the Tyne through cropping out along a plane which is not very much eroded, but south of the Tyne it causes waterfalls through cropping out by deep erosion of overlying rocks. The exposure on the Cross Fell escarpment is also notched by waterfalls.

4. The remaining district is that connecting the watersheds on the west of the North and South Tyne Rivers.

Hitherto the influences of the Pennine and Tindale (Stublick) Faults upon the junction-plane have been taken as guides to the

FIG. 8.—A bird's-eye view, looking south-eastwards from the Cheviots, of the Tyne area on the left and the Eden area on the right. Cross Fell is near the centre, and the Yorkshire coast (Mesozoic) is over the south-eastern watershed of the Tyne. The sections are from the Cheviots to Cullercoats on the left and Cheviots to the Lake District on the right, omitting the Permian and Trias. The bottom edges of the diagram are at sea-level. (Not drawn strictly to scale.)

river drainage. It is perhaps as well to continue on this line of inquiry. As is well known, the Pennine Fault throws down in a westerly direction and the Tindale Fault throws to the north. Should these two Faults intersect, there would be four fault faces at this intersection, and supposing the Mesozoic and Glacial deposits were removed we should see the south-east solid angle standing higher than the three others, while the north-western one would be the lowest of all through being thrown down by both faults. The depth at which the Palæozoic rock surface lies is not known, yet it is probably not so great as where it troughs under the Cumberland Plain and under the Solway.

Whatever the position of this old surface may have been in the past, we know that it is now buried under Mesozoic deposits. As these deposits were formed upon it, they would follow its general contours, their degree of dip having a tendency to lessen as they increase in thickness. When later movements set in, these deposits would still retain their parallelism with this buried surface. As a result of this, the present-day drainage system should be similar to that which would be formed upon this surface were the younger rocks removed and the land raised so as to be above sea-level. (Fig. 8.) The contour-lines of this surface would sweep round to the north-west on leaving the Tyne area and run towards the Cheviots. This change in direction on leaving the main valley of the Tyne would produce a watershed running in a northerly direction between the tributaries to the North Tyne and to the Eden from the north-east. As a result of this watershed and the westerly slope of the trough towards the Solway, no rivers would flow out of the Eden area into the Tyne area across the Pennine fault.

The configuration of the present drainage area of the Eden agrees very well with the construction above given, and therefore supports the mode of origin of this part of the Tyne watershed, the irregularities of which, as also in the other parts, are caused by later denudation producing sinuosities in its direction across country.

(To be concluded in our next number.)

III.—The Bekinkinite of Barshaw (Renfrewshire), and the Associated Rocks.[1]

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology, University of Glasgow.

Introduction.

THE recognition of teschenites in the Midland Valley of Scotland, first by Teall[2] and later by several other petrographers, has led to the discovery of numerous varieties of analcite-rich rocks in the same area.[3] One of the most interesting of these is the unique rock discovered in an old quarry at Barshaw near Paisley, during the remapping of the district by the officers of the Geological Survey of

[1] This paper forms part of the results of a research which has been aided by a grant from the Government Grant Committee of the Royal Society.

[2] *British Petrography*, 1888, p. 359.

[3] Tyrrell, Geol. Mag., Dec. V, Vol. IX, pp. 69–80, 120–31, 1912.

Scotland. A preliminary description of this rock as a weathered theralite was given by Mr. E. B. Bailey in 1909.[1] In the previous year a chemical analysis by Mr. E. G. Radley had appeared.[2] A fuller description is given in the Survey Memoir on the Glasgow District (1911).[3] According to Mr. R. G. Carruthers the theralite is probably part of an igneous mass which is persistently found at the Hurlet Limestone horizon of the Carboniferous Limestone Series in the Paisley district. The petrography of the rock, as investigated by Mr. Bailey, makes clear its relationship to the melanocratic ijolites of Madagascar described by Lacroix,[4] and named 'bekinkinite' by Rosenbusch.[5] It is considered as a special modification of the Paisley teschenite or dolerite.

The unique character of the rock in British petrography is sufficiently indicated by its identification with bekinkinite, which was formerly only known from the type-locality of Bekinkina in Madagascar. During recent visits to the Barshaw exposure other varieties of the rock were found, principally as schlieren drawn out as thin streaks in the predominant melanocratic or mesocratic variety. These schlieren provide mesocratic and leucocratic facies of the type, and are identical with the rock described as lugarite.[6] In view of the discovery of these varieties, the unique character of the rock, and the fact that the old quarry at Barshaw is on a building site and is being made a dump for refuse, it has been thought advisable to give a full description before the exposure disappears.

Field Relations.

The Barshaw bekinkinite is obtained from an old quarry situated in a plantation a little to the east of Barshaw House, 1½ miles east of Paisley, along the Glasgow road. The opening is very shallow, the greatest depth of rock seen being only 5 feet. The eastern part of the quarry shows a ledge of hard rock, the base of which consists of the melanocratic variety in a rather decomposed condition. Towards the top of the exposure irregular patches and streaks of a light-coloured pinkish rock, crowded with small black prisms and needles, begin to appear. These are usually drawn out into irregular streaks or schlieren, but sometimes form much-involved, irregularly-shaped patches embedded in the darker type. These 'facies de variation' show considerable differences amongst themselves in texture and the relative proportions of the black prismatic minerals (barkevikite and titanaugite), but the general contrast of the pale leucocratic schlieren with the predominant dark, basic, melanocratic type remains the most striking feature of the exposure. In all, including the melanocratic facies and the light-coloured schlieren (lugarite), no fewer than seven distinct varieties of rock may be distinguished by microscopic examination (see Petrography, *postea*). The leucocratic schlieren seem to be more abundant towards the top of the exposure, but the

[1] *Summary of Progress of Geological Survey for 1908*, 1909, p. 44.
[2] *Summary of Progress of Geological Survey for 1907*, 1908, p. 55.
[3] *Geology of the Glasgow District* (Mem. Geol. Surv.), 1911, pp. 116, 134.
[4] Nouv. Arch. Mus. (4), i, p. 135, 1902; ii, p. 227, 1903.
[5] Micr. Phys., ii, p. 441, 1907.
[6] Tyrrell, Geol. Mag., Dec. V, Vol. IX, pp. 77–8, 1912.

amount of rock visible is too small for this fact to have any distributional significance.

In the western corner of the quarry an exposure of decomposed rock shows a band of hard, grey, spotted material (variety No. 7), and three lenticular streaks of the leucocratic variety mentioned above.

The Barshaw exposure forms part of a persistent intrusion which appears near the Hurlet horizon in the Paisley district, and has been named the Hurlet sill.[1] A fine exposure occurs in the railway cutting at Arkleston, another at the Blackhall Quarry, and the River Cart near by. Exposures also occur at Seedhills and Old Crookston Farm. All these localities lie to the east of Paisley, and have been fully described by P. Macnair.[2] A sill is also seen in the old quarry at the Fossil Grove, Victoria Place, Whiteinch, on the north side of the Clyde.[3] According to the Geological Survey this exposure belongs to the Hosie sill, a small intrusion from 24 to 30 feet in thickness, which occurs near the Hosie Limestone horizon, about 20 fathoms above the Hurlet sill.[4] Mr. Macnair thinks it highly probable that the Seedhills, Blackhall, Arkleston, and Whiteinch intrusions belong to the same great mass and are connected underground. Mr. R. G. Carruthers also, in the Glasgow Memoir, thinks it probable that the Hosie sill is an offshoot from the Hurlet.

At Arkleston and Blackhall the Hurlet sill has become involved with the Hurlet Coal, and has suffered great endomorphic metamorphism, resulting in that modification the extreme term of which is known as 'white trap'. This mode of alteration is general throughout the mass of the sill, except perhaps in the centre. It is consequently exceedingly difficult to trace any resemblance between these rocks and the Barshaw theralites. If the Barshaw exposure belongs to the Hurlet sill, it has ascended or descended in this area to a horizon devoid of carbonaceous material, and has escaped the 'white trap' mode of alteration.

The determination of the true petrographic character of the Hurlet sill (apart from the Barshaw exposure) is much hindered by its extensive decomposition. The freshest material occurs at Old Crookston Farm and at Hurlet. The latter rock is described in the Geological Survey Memoir on the Glasgow District (p. 133) as an ophitic dolerite with purple augite, abundant olivine, and but little analcite. It is stated to resemble somewhat the Gallaston type of Fife. This description well fits the rock from Old Crookston Farm. My specimen shows numerous areas of chlorite rosettes which doubtless obscure areas of analcite, as they do in other undoubted analcite rocks from the same region. Areas of calcite also occur in polygonal spaces between the felspars in such a way as to suggest that they have replaced analcite. Alkali-felspar (probably soda-orthoclase) may also occasionally be detected in small quantity. The rock from the centre of the Arkleston sill is of the same general character, but is finer-grained, and its augite has a very deep purplish tint. These rocks are very similar to the types termed alkali-dolerite

[1] *Geology of the Glasgow District* (Mem. Geol. Surv.), 1911, p. 116.

[2] Trans. Glasgow Geol. Soc., vol. xiii, pt. i, pp. 58–60, 1907.

[3] Rutley, Q.J.G.S., vol. xlv, pp. 626–32, 1889. [4] Glasgow Memoir, p. 117.

and essexite-dolerite from the Ayrshire province [1] and to the crinanites of Argyllshire and Arran.[2] It is worthy of note that the essexite-dolerites of Ayrshire are intimately associated with certain highly analcitic types.

Mineralogical Description.

All varieties of the Barshaw rocks described later contain the same set of minerals, and differ only in the relative proportions of each. It is therefore convenient to describe the mineral constituents together. These minerals are titanaugite, barkevikite, ægirine, ilmenite, olivine, apatite; nepheline, analcite, plagioclase, orthoclase; with various decomposition-products.

The *titanaugite* is a deeply-coloured variety, with a relatively intense pleochroism, ranging from a clear pale brown to a deep maroon or purple-madder tint. The colours are very patchy in their distribution. Sometimes they form regular zoning parallel with the margin of the crystal, sometimes a good hour-glass structure. More often the tints have no regular distribution; but the different parts are generally separated by a sharp distinct line, and do not fade one into the other. Occasionally there is a narrow exterior zone of green ægirine-augite. The double refraction is high, with strong dispersion of the bisectrices, so that sections parallel to the symmetry-plane do not give complete extinction in white light. It is euhedral to all minerals save olivine and plagioclase. It is often irregularly indented by the terminations of the latter crystals.

The amphibole is a deep red-brown variety, referred to *barkevikite*. It is highly pleochroic, the extremes of colour being clear pale yellow and a deep red-brown. The latter has often a faint purplish shade. There is frequently a very narrow exterior zone of greenish or bluish material (arfvedsonite ?). Many sections have a small irregular core or central interlamellation of titanaugite in parallel intergrowth, and these are undoubtedly primary crystals which have grown upon a core of augite. Most of the barkevikite is primary, and in some of the rocks it is unaccompanied by titanaugite. Where, however, the latter is in excess, as in the melanocratic type, the amphibole forms a more or less broad exterior margin to the augite crystal, having an outer crystalline form, but with extremely ragged, irregular, interior margins against the pyroxene. Here it is clearly an outgrowth upon the pyroxene, not due to weathering, but to molecular instability of the pyroxene during or after crystallization. The barkevikite may enclose the terminations of felspar laths of early crystallization, but both it and the pyroxene is occasionally found enclosed within the later, highly-zonal plagioclase.

Small crystals of deep green *ægirine* occur enclosed in the analcite and nepheline.

Ilmenite occurs in skeletal crystals which frequently have an external euhedral form. It is always partially altered to leucoxene or granular sphene, and frequently presents a barred appearance; or unaltered ilmenite is left as an external zone around a core of

[1] Tyrrell, Geol. Mag., Dec. V, Vol. IX, p. 124, 1912.
[2] Tyrrell, Geol. Mag., Dec. VI, Vol. X, p. 307, 1913.

leucoxene. It presents varying relations to the pyroxenes and amphiboles, and is sometimes moulded on them and sometimes enclosed. All three minerals were crystallizing simultaneously and with nearly the same period of crystallization. The felspar, however, overlaps all the coloured minerals. It began crystallizing before, and finished after them.

Olivine only occurs abundantly in the bekinkinite, and is very rare in the lugarites. It forms rounded crystals, and is invariably altered to a deep-green serpentine.

The groundmass in which the coloured minerals are set is largely a confused mass of greyish alteration-products flecked with green, in which plagioclase, nepheline, and analcite may be identified in the fresher rocks.

The *plagioclase* was originally euhedral, but has now extremely irregular outlines due to intense corrosion by the hot, aqueous, alkaline residues, which subsequently crystallized as nepheline and analcite. The margins of the crystals invariably fade away into the turbid material which constitutes most of the groundmass of the rock. It is markedly zonal, and albite twinning is not well developed. Moreover, the partial or complete analcitization makes measurable extinctions hard to find. In the bekinkinite slides a single measurement gave symmetrical extinction-angles of 30½° ($Ab_1 An_1$); and in the lugarites two measurements gave 15 and 20°, indicating a composition near $Ab_5 An_3$. The analcitization of the felspars is very advanced. The crystals are filled with patches and veins of analcite which has spread in irregular masses from the cleavages.

Orthoclase occurs rather abundantly in the more leucocratic rocks, and generally forms a broad marginal zone to the plagioclase felspars. It is easily distinguished from the nepheline by its different mode of alteration and by its relation to the lime-soda felspars. It is generally in process of decomposition with the formation of a fine greyish dust, which contrasts with the yellowish streaky appearance produced by the alteration of the nepheline.

The *nepheline* is euhedral towards the abundant analcitic groundmass, and in one rock it is euhedral towards orthoclase. It occurs in well-shaped rectangular and hexagonal sections which are largely outlined in a very minute dust, composed of yellowish micaceous scales. This occasionally covers the whole section, but usually alternates in a streaky fashion with colourless and apparently unaltered material. The latter gives extremely low double refraction, and extinguishes in the direction of streakiness. The outlines of the crystals are often lost in decomposition products, producing very irregular fragments. Occasionally the nepheline forms large plates enclosing the other constituents, especially minute crystals of ægirine. The clear portions of the crystals are optically negative in the direction of streakiness, parallel to the longer edges of the rectangular sections. Its refractive index is well below that of Canada balsam, and the mineral is probably identical with the 'nepheline x' of Bailey, which is distinguished from ordinary nepheline by its lower refractive index.[1] Mr. Bailey has also noted the occurrence of 'nepheline x'

[1] *Geology of East Lothian* (Mem. Geol. Surv.), 1910, p. 110.

in one of the Barshaw rocks, as well as in the essexites of Crawfordjohn and Lennoxtown, and the nepheline-teschenite of Cathcart.[1]

Another mineral is closely associated with the nepheline, and weathers in much the same way. It is generally intergrown with nepheline in alternating streaks. It differs from nepheline principally in its double refraction, which is apparently a little higher than that of quartz. It polarizes in straw yellow and reddish tints. The mineral has a good cross-fracture, and is optically positive with regard to the direction of elongation, and perpendicular to the cross-fracture. Its refractive index is somewhat higher than that of nepheline. The crystals are occasionally shaped like those of nepheline, giving rise to the suspicion that the mineral may be pseudomorphous after nepheline. Frequently, however, it forms irregular plates, which enclose crowds of small needles of barkevikite.

This mineral appears to be identical with that described by Bailey as associated with 'nepheline x' (East Lothian Memoir, p. 111). Mr. Bailey also states that it occurs in the West of Scotland associated with 'nepheline x', but makes no mention of it in the petrographical chapter of the Glasgow Memoir.

Petrography.

1. The Bekinkinite.—This is the most melanocratic type found at Barshaw, and occurs at the base of the exposure.

The most abundant mineral is titanaugite, usually intergrown with barkevikite. The latter rarely forms independent crystals. The next most abundant mineral is olivine, completely altered to a green serpentine. The iron-ores include ilmenite and pyrite. The subordinate groundmass consists of corroded felspar, altered nepheline, and analcite, the latter occasionally quite fresh. The nepheline forms large anhedral plates, which enclose the minerals of earlier consolidation. The general decomposition of the leucocratic minerals renders the elucidation of their mutual relations rather difficult. The plagioclase is always earlier than the felspathoids, and is invariably corroded, and clearly reacted upon by the hot alkaline solution in which it crystallized. Mr. Bailey believes that the analcite is derived from the alteration of the nepheline.[2] Our rock is too decomposed to give decisive evidence upon this point, but in the other rocks of this series the nepheline is frequently euhedral to the analcite, and does not appear to pass into it. Moreover, the nepheline has its own distinctive mode of alteration. The chemical composition of this rock is shown in the Glasgow Memoir, where it is compared with other Scottish rocks and the type bekinkinites of Madagascar (Glasgow Memoir, p. 134). Its chemical composition is further discussed in this paper (Table I), and its quantitative mineral composition has been determined (Table II).

2. Lugarite.—The six varieties described below may all be grouped together under the term lugarite. This name was applied to a unique rock occurring in the Lugar sill, which may be interpreted as an ijolite in which nepheline is partly or wholly displaced by analcite,

[1] *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, p. 128.

[2] Ibid., p. 134.

and in which barkevikite is a prominent constituent as well as augite.[1] A description of this rock is given in the above cited paper; but since this was published a chemical analysis of the type-rock has been made by Mr. Alex. Scott (Table I) which fully bears out its diagnosis as a new type. Mr. Scott has also executed an analysis of the Barshaw lugarite (Table I), which shows a very close resemblance to the type-rock of Lugar. The quantitative mineral composition of some of these rocks is shown in Table II.

Variety 1.—This rock occurs about the middle of the Barshaw exposure, overlying the bekinkinite. It is decidedly less melanocratic than the latter rock, as is shown in Table II. It may be described as a mesocratic facies, in which there is approximate equality between the lighter and darker constituents. It is characterized by the abundance of equidimensional and euhedral titanaugite, which is of a highly pleochroic variety. Outgrowths of barkevikite occur, but are comparatively rare, whilst ilmenite, in process of alteration to leucoxene, has increased in amount as compared with the bekinkinite. The leucocratic groundmass is much altered, but large patches of orthoclase may be seen, as well as areas of analcite which frequently shows anomalous birefringence. The nepheline is completely altered to a dusty yellowish material. Very faint 'ghosts' of plagioclase felspars occur in the turbid groundmass.

Variety 2.—This variety forms the major portion of the schlieren towards the top of the exposure. It is an even-grained mesocratic rock characterized by the abundance of red euhedral barkevikite, as well as the purple titanaugite, often in intergrowth. The groundmass in this rock is comparatively fresh. In it may be recognized clear, fresh plagioclase, often corroded and traversed by anastomosing veins of analcite. The felspar crystals are often eaten out by analcite, leaving very ragged remains embedded in the latter mineral. Orthoclase occurs rather abundantly, either as marginal zones to the plagioclase felspars, or much altered and only recognizable in small clear patches surrounded by various alteration products. Nepheline occurs in broad anhedral plates with the characteristic streaky alteration, and poikilitically enclosing the earlier constituents. There is some clear interstitial analcite. When enclosed in nepheline the pyroxene becomes a variety close to ægirine; and the crystals of titanaugite always have a narrow green marginal zone where they abut on nepheline or analcite. The nepheline, and the leucocratic groundmass in general, is riddled with needles of apatite. This rock differs from the preceding only in that the quantitative relations of titanaugite and barkevikite are reversed (Table II).

Variety 3.—This occurs in schlieren along with the preceding type. It is a rock of a pinkish colour, and containing black prisms of barkevikite. In thin section it is seen to be a leucocratic development of the preceding variety. The ferromagnesian minerals have dwindled in quantity and size. Titanaugite has totally disappeared, and barkevikite alone is left in any quantity. On the other hand there is a development of minute prisms of ægirine-augite, enclosed

[1] Tyrrell, Geol. Mag., Dec. V, Vol. IX, pp. 77–8, 1912.

in the felsic constituents. Ilmenite is present, but in very small amount. Amongst the predominant felsic or leucocratic minerals nepheline is the most conspicuous. It occurs in well-formed crystals which are euhedral toward analcite and orthoclase, but not to plagioclase. Orthoclase is more prominent than plagioclase, whilst the latter is highly analcitized. Analcite, with anomalous double refraction, fills up the interspaces.

Variety 4.—This occurs closely associated with the two preceding varieties in thin streaks or schlieren that have been drawn out together during intrusion. It is chiefly distinguished from variety 3, which it closely resembles otherwise, by its much finer grain. Barkevikite is especially prominent in small prisms, and is intergrown in very irregular fashion with titanaugite. This, and the succeeding variety, are little more than textural modifications of varieties 2 and 3.

Variety 5.—This schlier resembles variety 4 in granularity and generally in mineral content, but is devoid of titanaugite. The barkevikite has an acicular habit which makes this a striking and easily recognized type. In the hand-specimens the barkevikite forms numerous black needles embedded in a pinkish groundmass. This rock is rich in nepheline, and in the unknown mineral which resembles and occurs along with the nepheline. The nepheline is well-shaped and is usually crowded with prisms of barkevikite. Analcite occurs in considerable quantity, and orthoclase is dominant over plagioclase.

Variety 6.—This is a white-spotted rock from the exposure on the west side of the quarry, and is characterized by its richness in small, perfectly euhedral crystals of titanaugite. Barkevikite is in subordinate quantity. The rock is also characterized by containing more or less rounded areas of the felsic minerals, almost completely devoid of the coloured constituents. These appear as white spots in the hand-specimens and slides. Growths of chlorite rosettes occasionally form some proportion of these spots, and probably replace analcite. This rock appears to be a textural modification of variety 2.

(*To be concluded in August Number.*)

IV.—On a Marine Band in Middle Coal-measures, South Lancashire.

By R. L. Sherlock, D.Sc., A.R.C.S., F.G.S.

Up to the present marine fossils have been recorded in Middle Coal-measures in the South Lancashire Coal-field at two horizons only. They are (1) in the banks of the Tame, near Ashton-under-Lyne, found by Professor A. H. Green,[1] and at Ashton Moss Colliery, about 750 feet above the Great Mine, discovered by the late George Wild.[2] (2) Mr. H. Bolton, F.R.S.E., informs me that the Californian or Thin Bed of Fulledge Colliery, Burnley, which is 410 feet above the Arley Mine, is a marine horizon.

Mr. John Gerrard, in his Presidential Address to the Manchester Geological and Mining Society,[3] mentioned a marine band found at

[1] E. Hull, *Geology of the Country around Oldham* (Mem. Geol. Surv.), 1864.
[2] J. Gerrard, Trans. Inst. Min. Eng., vol. xxviii, p. 363, 1904. [3] Ibid.

Victoria Colliery, Standish, as probably near to the Arley Mine. He tells me that he is now of opinion that the strata were faulted and that the marine horizon really belongs to the Lower Coal-measures. So far as I know, there is no record of marine fossils in the Middle Coal-measures of the western part of the coal-field.

Recently, while examining a collection I made about the year 1890, I found a small slab of shale containing numerous marine fossils. The specimen was found on the tip-heap of the Alexandra Colliery, not many yards south-west of the Ravenhead Plate Glass Works, St. Helens. The shaft is situated on the outcrop of the Ravenhead Main Coal, according to the Geological Survey Map, and was sunk to the Little Delph (Arley Mine). The horizon of the marine band will therefore be somewhere between the Little Delph and the Ravenhead Main Coal, and it is probable that the fossils came from the roof of the Little Delph (Arley Mine). Mr. John Gerrard, who has a special knowledge of these strata and has examined the fossils, considers that the character of the stone confirms this idea. The specimen is a fragment of hard black shale, crowded with organic remains, many of them indeterminable, but amongst them *Pterinopecten papyraceus* (J. Sow.) and Goniatites are readily identifiable. A number of pieces of black shale collected at the same time and place, and similar to the fragment just mentioned, although looking somewhat less weathered, contained abundant fish-remains. Many of these were very fragmentary, but others have been named by Mr. W. Manson, who has compiled the following list:—

On a single fragment of shale—

Pterinopecten papyraceus (J. Sow.).
Gastrioceras sp.
Orbiculoidea ?

The following are on similar black shale collected at the same time and place:—

Elonichthys aitkeni, Traquair (fine specimen).
Rhizodopsis sauroides (Will) (scale).
Megalichthys hibberti ? Ag. (scales and teeth).
Cœlacanthus sp.
Lepidostrobus variabilis ? L. & H. (with fish-remains on the back).
Lepidodendron (with fish-remains on the back).

The specimens will be deposited in the St. Helens Corporation Museum.

In conclusion I wish to express my thanks to Mr. John Gerrard for the helpful information which he has given me.

V.—The Relation of the Coal-measures to the Lower Carboniferous Rocks in the Clapton–Clevedon District, Somersetshire.

By Frank Dixey, B.Sc., F.G.S., Assistant Lecturer in Geology, University College, Cardiff.

THIS paper gives the results of investigations made during the early part of the present year with the object of elucidating the relation of the Coal-measures to the Lower Carboniferous rocks in the Clapton and Clevedon districts of Somersetshire.

The Carboniferous Limestone forms a ridge which extends eastwards from Clevedon to beyond Clapton in Gordano. On the northern flank of this ridge lie two separate outliers of Coal-measures. In the east, around Clapton in Gordano, the Coal-measures cover a considerable area and constitute the Clapton Coal-field, but in the west their outcrop forms only a narrow discontinuous strip which extends as far as Clevedon.

A glance at the Geological Survey map [1] of this district shows that the relation between the Lower and Upper Carboniferous is an abnormal one. In the neighbourhood of Clapton in Gordano, the southern boundary of the Coal-measures transgresses the outcrops of the Carboniferous Limestone, the Lower Limestone Shales, and the Old Red Sandstone, and the Coal-measures enclose several small patches of Carboniferous Limestone. Moreover, whereas the Lower Carboniferous and older strata possess a variable but persistent southern dip, the Coal-measures dip to the north and north-west.

In the Geological Survey memoir on East Somerset and the Bristol Coal-fields,[2] the Coal-measures of the Clapton area are assigned mainly to the Pennant Grit or Middle Series of the Bristol and Somerset Coal-fields. The only reference made to the anomalous relation of the Coal-measures and the Carboniferous Limestone is contained in the following passage [3]: "Around Clapton in Gordano are several patches of Carboniferous Limestone occurring in the midst of Coal-measures, positions which it seems difficult to account for."

Professor C. Lloyd Morgan maintained [4] that the small isolated masses of Carboniferous Limestone are the remnants of a sheet of Carboniferous Limestone which was carried down over the Coal-measures by a "flat-lying fault".

Dr. A. Vaughan, however, in his paper on the Carboniferous Limestone of the Bristol area,[5] wrote as follows: "I am strongly inclined to believe that there is, in this region, evidence of post-Tournaisian upheaval and denudation, and that the area was not again submerged until the Coal-measures were laid down in a narrow inlet, bounded on the west by the Clevedon–Portishead ridge and on the south by the western part of the Clevedon–Failand ridge. Within this inlet, the masses of Carboniferous Limestone in the Clapton district stood up as small islands."

My own observations in this district confirm the unconformable relation of the Coal-measures to the Lower Carboniferous and the Old Red Sandstone. It is evident that, in Carboniferous times, the district suffered not only considerable folding, but also much faulting, as shown by the relative position of the 'islands' and main outcrop of the Carboniferous Limestone.

[1] Sheet 19 (Old Series), Somersetshire.

[2] *Geology of East Somerset and the Bristol Coalfields* (Mem. Geol. Surv.), 1876, p. 45.

[3] Ibid., p. 42.

[4] "Geology of the Avon Basin (Portbury and Clapton Districts)": Proc. Bristol Nat. Soc., N.S., vol. v, 1885–8, p. 44.

[5] "Palæontological Sequence in the Bristol area": Q.J.G.S., vol. lxi, 1905, p. 232.

Unconformity between the Coal-measures and the Lower Carboniferous has recently been demonstrated in the Titterstone Clee Hills by Mr. E. E. L. Dixon,[1] and in the Forest of Dean Coal-field by Professor T. Franklin Sibly.[2]

This investigation was undertaken at Professor Sibly's suggestion, and I have great pleasure in recording my indebtedness to him for advice and helpful criticism.

Review of Field Evidence.

Eastern District (The Clapton Coal-field).

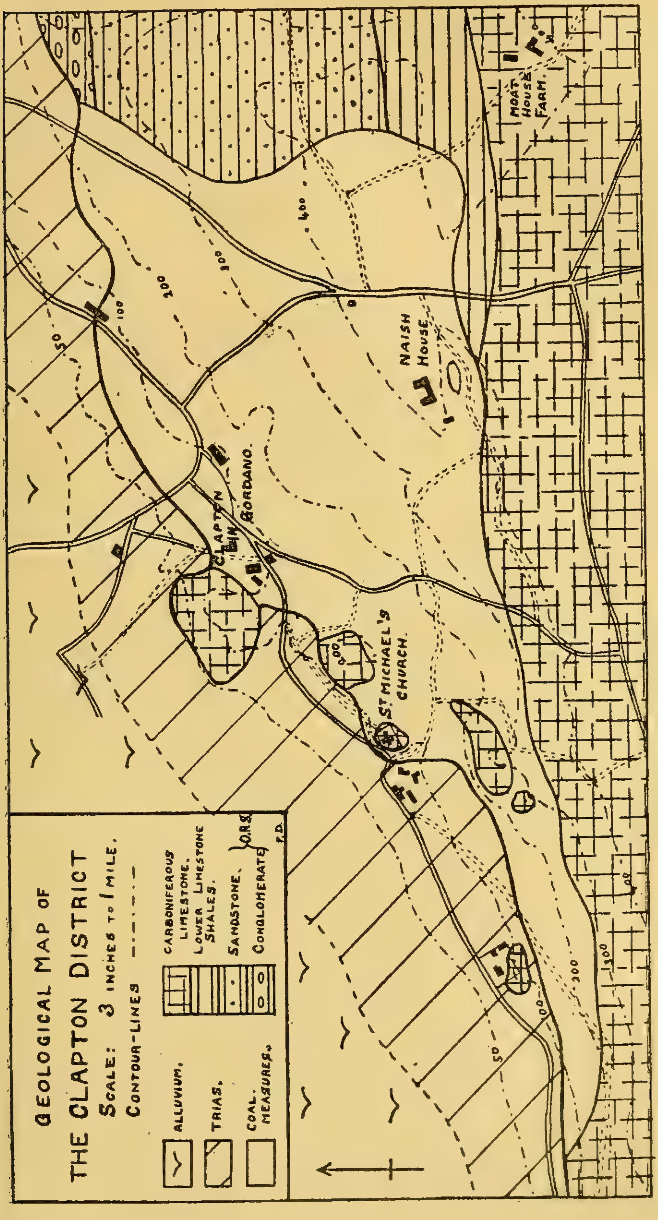
This area has been mapped on the scale of 6 inches to 1 mile. It furnishes conclusive evidence of unconformity between the Coal-measures and the older strata. On the north the Coal-measures sink beneath the Trias, but on the east and south they are bounded by the Old Red Sandstone and the Carboniferous Limestone Series. The unconformity may be demonstrated in three ways: (1) By the overstep of the Coal-measures from the Carboniferous Limestone across the Lower Limestone Shales on to the Old Red Sandstone. (2) By the occurrence of small 'islands' of Carboniferous Limestone which rise through a covering of Coal-measures. (3) By angular discordance between the Coal-measures and Carboniferous Limestone; this is suggested by the general northerly dip of the Coal-measures and southerly dip of the older rocks, and it is proved by small exposures in the neighbourhood of Clapton Church (St. Michael's).

1. The southern and eastern boundary of the Coal-measures has been carefully traced. Its transgressive nature is quite evident from the map, and the overstep can be definitely proved on the ground immediately south and east of Naish House. Near Naish House the boundary gradually crosses from the Carboniferous Limestone, the base of which continues as a low escarpment due east towards Moat House Farm, on to the Lower Limestone Shales. It extends a short distance eastwards along the little strike valley in the Lower Limestone Shales (where a spring is thrown out from the Pennant Grit by the underlying Lower Limestone Shales), and then swings northward somewhat suddenly until the Coal-measures rest directly upon the Old Red Sandstone.

2. The 'islands' of Carboniferous Limestone usually form little rounded and wooded knolls. The largest, that immediately west of Clapton village, lies on the margin of the Coal-measures, and is for the most part surrounded by Trias. The other knolls, five in number, are situated within less than a mile to the south-west; three of them are entirely, and a fourth is partly, enclosed by Coal-measures. The small knoll upon which St. Michael's Church stands is bounded on all sides by the Coal-measures, which are clearly seen in several places to rest upon the Limestone.

3. The unconformable junction between the Coal-measures and the Carboniferous Limestone is best seen in a small excavation on the eastern side of the field path which leads northwards from the

[1] Geol. Mag., Dec. V, Vol. VII, p. 458, 1910.
[2] Geol. Mag., Dec. V, Vol. IX, p. 420, 1912.


GEOLOGICAL MAP OF
THE CLAPTON DISTRICT
SCALE: 3 INCHES TO 1 MILE.
CONTOUR-LINES
ALLUVIUM.
TRIAS.
COAL-MEASURES.
CARBONIFEROUS LIMESTONE.
LOWER LIMESTONE SHALES.
SANDSTONE.
CONGLOMERATE
O.R.S.
MOAT HOUSE FARM.
NAISH HOUSE
CLAPTON IN GORDANO.
ST MICHAEL'S CHURCH.
400
300
200
100
50

churchyard. Here flaggy sandstones with a low southerly dip rest upon an irregular surface of massive limestone. These sandstones are coarse in texture and highly calcareous, and, like most of the Pennant Grit of this district occurring at a low altitude, have been stained red by the Keuper which once overlay them. The angular discordance is demonstrable in a small exposure at the foot of an ash-tree, half-way down the steep bank between the north-west wall of the churchyard and the road. The Pennant here shows the same dip as in the previous section, and in this case the underlying limestone can be clearly seen to dip southward at a larger angle. Although the actual junction is not well defined at any other point, there are numerous very small exposures of both Pennant and Carboniferous Limestone on the northern and western sides of the knoll upon which the church is built; and apart from its occurrence in the section described, angular discordance is indicated by the dips shown in all these closely adjacent exposures. It is of interest to trace within about 50 yards the gradual passage of the calcareous and highly stained sandstone to the normal blue-grey Pennant Flagstone. On the western side of the church is a deep cutting running to the south and east, in which this change can be followed. Sandstones precisely similar to those seen resting on the limestone close to the churchyard are found to lose their calcareous character and rich staining when they are traced southwards, and, moreover, plant-remains become abundant.

Western District (Clevedon Area).

This district includes the Coal-measures exposed on Strawberry Hill and Court Hill, near Clevedon. The original relation of these to the older rocks has been masked by faulting, which has brought the Coal-measures against the Carboniferous Limestone, and the fault can be traced directly down the steep slopes of the gap which separates the two hills. The faulting is doubtless connected with the profound disturbances that gave rise to the two ridges of Carboniferous Limestone which converge at Clevedon. I hope to continue my investigation of the geological structure of this area.

VI.—Studies in Edrioasteroidea, VIII. A Comparison with the Structure of Asterozoa.

By F. A. Bather, M.A., D.Sc., F.R.S.

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THE resemblance of the oral face of an Edrioasteroid to an Asteroid has not merely been remarked on by nearly every writer on the group, but has led many of them to far-reaching conclusions (e.g. Steinmann, 1888; Neumayr, 1889). None the less no exact comparison of the structures has yet been made; nor indeed was such possible until accurate descriptions were available. These have now been provided for various recent and fossil Asterozoa by many writers referred to in the sequel, and especially by Mr. W. K. Spencer (1914, "Monogr. Brit. Palæoz. Asterozoa"; Palæontogr. Soc.).

In general shape the Edrioasteroidea are more rounded and less stellate than the starfish. This is a natural consequence of the mode of life of the two classes. The Edrioasteroid that appears to have been the least sedentary, namely *Stromatocystis*, is also the most stellate. Similarly in Asteroidea the active Asteriidæ have, as a rule, longer arms than the more sluggish Asterinidæ and Echinasteridæ. Mere outline, then, has little genetic significance; the distinction, if any, lies in the large development of interambulacral plates in the Edrioasteroidea and their lack of marginalia, for the 'marginals' of *Agelacrinus* are scarcely homologous with those of Asteroidea. The observations of Mr. Spencer, however, "show that the most primitive Asterozoa have a leathery skin in which are imbedded small irregular plates" (p. 34), and that many of them "are devoid of differentiated marginalia" (p. 20). The specialization of the irregular plates into marginalia or other skeletal elements differed in the different branches of Asterozoa (Spencer, p. 8), just as it differed in the various genera of Edrioasteroidea. The ossicles of fundamental importance are those which were "the first to be laid down" or, at any rate, to be specialized from the indifferent coating of plates, namely, "those associated with the water-vascular system (ossicles of the ambulacral groove and mouth-frame)." It is to these, then, that our attention must be directed.

In the older Asterozoa, from which the true Asteroidea and Ophiuroidea were derived, the plates which in a modern starfish are known as "Ambulacralia" were "little more than mere flooring plates to the ambulacral grove" (Spencer, p. 21). They formed a double series, either opposed as in recent Asteroidea, or alternating as in *Edrioaster*. Spencer, following Gregory and Jaekel, regards the latter arrangement as the more primitive. These ambulacrals were approximately rectangular in plan, and excavated along the perradial sutures by a shallow "ambulacral channel" for the radial water-vessel. Along the sutures at right-angles to this the plates were deeply excavate, leaving a well-marked median transverse ridge along each. The longitudinal ridge, parallel to the ambulacral channel, was but slight, indicating the feeble development of the transverse ventral muscles.

Thus far the description is equally applicable to *Edrioaster*, but the difference from both *Edrioaster* and the true Asteroidea lies in the alleged absence of podial pores. It is presumed that branches led from the perradial water-vessel to podia placed somewhere in the depressions between the ridges; and it is possible that these depressions indicate the presence of incipient ampullæ; but, according to Mr. Spencer, the ampullæ had not yet penetrated to the interior. Were that view correct, *Edrioaster* itself would be more advanced in this respect than the older Palæozoic Asterozoa, and would find its analogue in such a form as the Lower Devonian *Xenaster*, where the pores have the same relative size and position (see Schöndorf, 1909, Palæontographica, vol. 56, pl. xi, fig. 2).

In reference to the earlier Asterozoa, Mr. Spencer says (p. 18): "Many investigators, owing to the poor state of preservation of their material, have described these depressions as pores for the passage of ampullæ." This is probably true, and yet it does not follow that pores were not developed before Devonian time, or even that they were absent in the very cases to which Mr. Spencer refers. The true pores in *Xenaster* are difficult to see, by reason both of their position and their small size; they were probably even more difficult to see in the predecessors of *Xenaster*. Take *Lindstromaster*, for instance, from the Wenlockian of Gotland. Dr. J. W. Gregory, in his exceedingly succinct account (Geol. Mag., 1899, p. 347), said: "The ambulacral plates are boot-shaped. The pores for the podia are large." Apparently these statements were based on plates in which the depression was still partly filled by matrix. In other regions, however, the matrix has been most carefully removed, and the true structure is represented in Liljevall's accurate drawing (Geol. Mag., 1899, pl. xvi, fig. 1*b*, the ray in the south-east position, on the west and east sides of it respectively). The details are obscured in the half-tone reproduction, but I had the opportunity of comparing the original with the specimen itself in special reference to this point. The median ridges of the floor-plates run diagonally from the proximal adradial corner to the distal outer corner of each plate, so that, if the sutures be not carefully observed, the plates appear to be directed distalwards as they pass outwards. The sutures, however, really pass in the contrary direction. Thus the position where the pore should be looked for is where the suture meets the outer end of the ridge. Here the pore is indicated by Liljevall, almost hidden by the ridge and the overhanging "adambulacral", and here it does seem really to occur in the specimen, though proof by sections or grinding down is wanting.

If pores were absent in all the pre-Devonian Asterozoa, it would be very difficult to understand how the relatively narrow pores of *Xenaster* were formed. Starting with pressure of an incipient ampulla outside the floor-plates, one would expect to observe a gradual deepening of the excavation until it broke through into the thecal cavity as a relatively wide hole. Such is in fact the appearance presented by Professor Jaekel's drawing of *Siluraster perfectus*, from the uppermost Ordovician of Bohemia (November, 1903; Zeitschr. deutsch. Geol. Gesell., vol. 55, Protokoll. p. 108 = p. 15). As our knowledge increases it may be that we shall find among the early Asterozoa, as among the Edrioasteroidea, some genera with podial pores, others without, forming parallel lines of descent. The presence of endothecal ampullae is necessarily dependent on the existence in the rays of a thecal cavity large enough to contain them.

The Cover-plates of *Edrioaster* appear to find their homologue in the so-called "Adambulacralia" of the starfish. These elements are thus described by Spencer in *Archaster typicus* (p. 13): "They are irregularly pentagonal in shape. The outer side runs almost parallel with the length of the groove. The face nearest to the groove has two facets [i.e. two sides of the pentagon]. The proximal facet is short and straight, the distal facet somewhat longer and slightly concave. We shall see that the appearance thus presented is characteristic of primitive Asterozoa and primitive Ophiuroidea as well as of the Asteroidea." This description applies almost exactly to the cover-plates of *Edrioaster*, as may best be seen by a comparison with Text-figure 2 of Study IV (1914, p. 164). The difference lies in the greater development of articulating muscles and their surfaces of attachment in *Archaster*, especially in the fact that the adambulacrals are united to each other by a longitudinal muscle. It may also be noted that in *Archaster* each adambulacral is attached to two ambulacrals (floor-plates); Mr. Spencer, however, points out that the attachments are not really equal, as so frequently implied for this and other modern asteroids, but that one of the attachments preponderates and "connects the ambulacral to the adambulacral with which it corresponds in the series". In the early Palæozoic Asteroidea each ambulacral is associated only with its own adambulacral, just as in *Edrioaster* each floor-plate has its cover-plate. In these early forms also, as appears from the descriptions of Schöndorf, Hudson, and Spencer, the articulating sculpture and muscle-connections were much less developed.

The cover-plates of the Agelacrinidæ, recently so well described by Dr. Foerste (1914, §§ 16 and 22) are in some respects even more like Asteroid adambulacrals. The inequality of the admedian sides ('facets' W.K.S., *loc. cit.*) is generally exaggerated, so that in plan the visible portion of the cover-plate "has a spinous prolongation on the proximal side" (Foerste), or is "shaped like a bent finger" (Spencer, 1904), or is what J. W. Gregory calls 'boot-shaped', with the sole towards the mouth. Further, as Foerste has shown, in many of the Ordovician species the vertical section of a cover-plate is roughly sickle-shaped (or boomerang-shaped), the blade corresponding to the part which arches over the groove, and the handle to a narrower extension beneath the adjacent interambulacrals. Where blade and handle join is a slight groove between two ridges, forming an articulation with the floor-plate. Similar passage of the adambulacrals beneath the adjacent interambulacral (ventro-lateral) plates may be seen in many modern starfish. The chief difference is that the cover-plates of Agelacrinidæ are not one to each floor-plate; but this doubtless is due to the fusion of the floor-plates into groups, as already explained.

The adambulacrals of starfish do not close down over the groove in the same way as did the cover-plates of *Edrioaster*, and the contents of the groove are generally protected by groove-spines borne on the adradial margin of the adambulacral plates. None the less, by the approximation of the two sides of the groove, effected by the ventral cross-muscles, the adambulacrals may be brought quite close together, and in some species they may when thus closed be observed to alternate just like the cover-plates of an Edrioasteroid. See, for example, Ludwig, 1905, "Asteroidea of the Albatross," Mem. Mus. Comp. Zool. Harvard, vol. 33, fig. 51, *Pentagonaster ernesti*, fig. 135, *Paulia horrida*; Koehler, 1910, "Shallow-water Ast. Indian Mus.," pl. xi, fig. 3, *Pentaceros indicus*, pl. xii, fig. 2, *P. reinhardti*, and others; Gregory, 1899, op. cit. fig. 1*b*, *Lindstromaster*, the ray in the north-west position.

The alleged invariable presence of groove-spines, and the frequent presence of other spines on the adambulacrals of Asteroidea does not constitute any serious difference. Spines were borne by the cover-plates in *Pyrgocystis sardesoni*, and reason has been given for supposing that they occurred in some other species of Edrioasteroidea. But since the cover-plates were in themselves sufficient protection for the grooves, there was not the same need for spines as arose in starfish with their more open grooves.

The Mouth-Frame of a modern starfish consists of five sets of paired radially placed elements and five sets of paired interradially placed elements. The latter, known as the "mouth-angle plates", are continuous with the adambulacrals, and are generally considered to be serially homologous with them. At any rate, they probably contain adambulacral elements, even if they may have incorporated some other constituent. The radially placed elements are admittedly ambulacrals (floor-plates) slightly modified. Morphologically then all these elements belong to the skeleton of the radial grooves. There is, however, another element, the so-called 'odontophore', lying in each interradius and abutting on the mouth-angle plates; whatever its ultimate origin, it presents the appearance of an unpaired interradial element.

For the present purpose it is quite unnecessary to enter into the perennial discussion as to the precise homologies of all these plates in Recent Asteroidea and Ophiuroidea. Comparison need be made only with the early Palæozoic Asterozoa, and here the problem is much simpler.

As an example of a very primitive mouth-frame Mr. Spencer (1914, p. 30) takes the fossil which he names *Eoactis simplex*.[1] His drawing (pl. i, fig. 4) shows a simple series of ambulacrals and of adambulacrals. At the proximal end of the groove the ambulacrals diverge, and the series is there terminated on each side by a curved subtriangular plate, which Mr. Spencer designates "mouth-angle plate". It is, however, clear from his drawing, no less than from the specimen itself, that this plate continues the ambulacral series and not the adambulacral, and this is further emphasized by the fact that the depression for the first podium lies equally on this plate and on the adjacent ambulacral. Further examination of other interradii in the fossil shows that this ambulacral mouth-angle plate was actually overlaid by a paired adambulacral element, though only the empty space that might have been occupied by such a plate is shown in the drawing. It follows from this that the plates marked by Mr. Spencer as A_1 and Ad_1 were really A_2 and Ad_2, and that the true proximal ambulacral and its corresponding adambulacral had not yet fused to form a mouth-angle plate. The continuity of the mouth-angle plate with the ambulacral series is also well illustrated by Spencer's drawing of those parts in *Stenaster obtusus* (1914, p. 32, text-fig. 28).

Turn now to the "series of schemes of buccal armatures of Palæozoic Ophiurids", published by Professor and Miss Sollas (1912, Phil. Trans., vol. 202, p. 226), and to Spencer's figure of *Lapworthura*

[1] This specimen, now in the British Museum, regd. E 13154, was No. 657 of the G. H. Morton collection, and comes from the Lower Ludlow or Upper Wenlock Beds of Hafod, Llandovery.

(1914, pl. i, fig. 9), and Jaekel's diagram of *Eophiura*, *Palaeura*, and *Bohemura* (1903), and it will be seen that the older the form, the more obvious is the composition of the mouth-frame from a series of ambulacrals diverging and becoming overlapped by the corresponding adambulacrals.

Perhaps the most instructive figure in this respect is that of the mouth-angle of *Siluraster perfectus* from the Upper Ordovician of Bohemia (Jaekel, 1903, fig. 3). Here is seen a series of adambulacrals each articulated with its corresponding ambulacral. The proximal adambulacral is enlarged to form a "Mundeckstück", but beneath it is still the ambulacral, though correspondingly reduced in size.

It seems a legitimate inference that all these plans of mouth-frame have been derived from one just a little simpler than the simplest of them, namely, a plan in which the ambulacrals were continuous right round the angle from ray to ray, each accompanied by its adambulacral. At first, no doubt, they were undifferentiated, so that the particular numerals attached to them, either here or in later forms, have no profound significance. Such a simple plan is essentially that of *Edrioaster* (Study IV, 1914, p. 164, Pl. xiv, fig. 2), but here already there is a condensation of the interradially placed floor-plates into a mouth-angle plate, a divergence of the proximal floor-plates of the groove, and an overlap producing in oral aspect the deceptive appearance of distinct perradial elements. The chief point of difference from any primitive Asterozoön lies in the fact that the adambulacrals of *Edrioaster* are still serving their primitive function as cover-plates.

The structure of *Edrioaster* suggests that even the interradially placed odontophore may be not of true interradial or interambulacral origin, but derived from the outer fused portion of the interradially placed floor-plates. On the other hand it is not quite certain that in *Edrioaster* itself this portion may not be in part an interambulacral with which the floor-plates have fused.

The curiously close resemblance between the ambulacral and peristomial structures of an Edrioasterid and those of a primitive Asterozoön would be strange indeed if their modes of feeding had been as different as those usually connoted by the names Pelmatozöon and Asteroid. We have, however, seen reason to believe that *Edrioaster* and *Dinocystis* were not permanently fixed; whence it may be inferred that they possessed some slight power of independent locomotion, towards which movements of the peripheral podia may have contributed. The existence of well-developed podia (a fact that cannot reasonably be doubted) further renders it probable that those organs helped in the transport of the larger food-particles to the mouth. Some Asteroids, on the other hand, and even some Ophiuroids, can use their podia for the same purpose; and some of the less active and less rapacious Asteroids can, as Dr. Gemmill has lately proved, subsist in part, if not entirely, by ciliary nutrition (March, 1915, Proc. Zool. Soc., pp. 1–19). Though a predatory mode of life was assumed at least as early as Devonian times by some starfishes with well-developed mouth-frame, e.g. *Xenaster eucharis* (see J. M. Clarke, 1912, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 15, pp. 115–18, pls. xiv–xvi), it is natural to suppose that the ciliary and podial method was that chiefly practised by those earlier Asterozoa in which the mouth-frame was still but slightly differentiated.

We have now reached this stage of our discussion: we have seen, on the one hand, that by the middle of the Ordovician Epoch certain Pelmatozoa had acquired a structure of the rays and of the peristome strangely like that of the Asteroidea; and, on the other hand, that the Asteroidea and, to a less extent, the Ophiuroidea, as they are traced back through the geological periods, approach more and more in the same respect to the structure of the Edrioasteridæ. The conclusion that suggests itself is obvious, but not necessarily correct. Many difficulties have to be smoothed away before a genetic filiation between the two groups can be maintained.

The statement, for instance, that Asteroidea occur in the Cambrian is frequently made, and is always quoted by those who regard the Starfish as a very primitive group, or who deny the possibility of their descent from a form similar to any Edrioasteroid. So long as the term Cambrian was extended to the summit of the Caradocian, the statement was admissible. Nowadays it is misleading. No Asterozoa are yet known below the Middle Ordovician; Edrioasteroidea are known from the Middle Cambrian, and typical Edrioasteridæ were contemporaries of the earliest known Starfish.

Other difficulties are presented by differences of structure and by certain features of the development. These will form the subject of the next Study.

VII.—A Contribution to the Petrology of North-Western Angola.

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

(*Continued from the June Number, p. 272.*[1])

5. Post-Cretaceous Alkaline Rocks between Senza do Itombe and Bango, Loanda.

The rocks described below were collected by Colonel Andrade, in 1904, on the road which begins at Senza do Itombe on the Loanda-Malanji Railway, and runs in a north-easterly direction to Bango. The localities, which lie strictly on the road itself, are determined by the following kilometre marks, measured from Senza:—

	km.
Nepheline syenite (foyaite)	near 24
Nepheline phonolite (brown)	,, 22
Olivine ulrichite (camptonitic tinguaite) . .	,, 20
Nepheline monchiquite (olivine-free) . . .	,, 20
Nepheline phonolite (grey) . . .	between 16 and 17

The intrusive rocks penetrate the Cretaceous formations of the district, which gradually die out towards Bango, where the Archæan

[1] In the Explanation of Plate XI, p. 272, the following corrections should be made: Fig. 3, for "wisp-like ferns" read "wisp-like forms"; Fig. 4, for "Phenolite" read "Phonolite"; for "magnification 40 in each case" read "magnification as indicated in each case".

platform reappears. The phonolites lie on the Cretaceous beds, but unfortunately their relations to the other members of the igneous suite has not yet been determined, and no order of intrusion can be stated. The whole suite of rocks is of post-Cretaceous and probably of Tertiary age. They have not, however, been seen in contact with Eocene or Miocene formations, which, although strongly developed on the west, are not now represented to the north-east of Senza.

NEPHELINE SYENITE [1] (FOYAITE TYPE).—In the hand-specimen the rock is seen to be made up chiefly of tabular felspars with conspicuous Carlsbad twinning, and nepheline. The felspar is white and grey in colour and the nepheline is similar, but sometimes exhibits a warmer tint. Idiomorphic crystals of pyroxene and sphene are scattered sparsely through the rock, making up less than 10 per cent of the whole.

The mineral composition as seen under the microscope is as follows. On the left the order is that of relative abundance; on the right it is that of crystallization.

Orthoclase and microperthite.	Zircon and apatite.
Nepheline and ægirine-augite.	Sphene and ilmenite.
Cancrinite.	Ægirine-augite.
Sphene and amphiboles (including hastingsite).	Biotite.
	Amphiboles and nepheline.
Apatite.	Cancrinite.
Ilmenite and biotite.	Orthoclase and microperthite.
Zircon.	

The *felspar* is almost entirely orthoclase, the proportion of perthitically intergrown albite being small. Carlsbad twinning is common, and most of the felspars are turbid, especially along cracks and cleavages, owing to the development of minute scales of sericite.

Nepheline is fresh and clear, though along the more conspicuous cracks micaceous alteration products are present. It is frequently idiomorphic towards orthoclase, and sometimes towards amphibole. *Cancrinite* is associated in small amount with the nepheline, occurring in parallel growth with the latter, or in irregular veins which traverse it. It can be easily distinguished from nepheline by its inferior refractive index and superior birefringence.

The coloured and accessory minerals have a strong tendency to aggregate together in groups, the chief members of which are ægirine-augite and sphene. *Ægirine-augite* occurs in well-shaped crystals, the central parts of which approximate to augite with a grey-green colour, or more rarely to titaniferous augite with a faint purple tint and a slight pleochroism. The outer borders are, however, of a bright green colour, and belong more nearly to ægirine proper than the main mass of the interiors.

Around these pyroxenes, and also around inclusions of magnetite or ilmenite within them, there is usually an irregular border of amphibole, the properties of which point to its being *hastingsite*.[2] The pleochroism and optical orientation are as follows:—

[1] Plate XI, Fig. 2.

[2] Adams & Barlow, *The Haliburton and Bancroft Areas* (Geol. Surv. Canada), 1910, p. 247. Quensel, Bull. Geol. Inst. Upsala, xii, p. 145, 1914.

X, near to a	brown-green	
Y, near to c	blue-green	$Z > Y > X$
$Z = b$	olive-green	

The extinction angle $Y \wedge c$ reaches a maximum of 35°. The birefringence is exceedingly low, being less than that of quartz, but on account of the strong axial dispersion the interference figure is coloured. The axial plane is at right angles to the plane of symmetry, and the optic axial angle is unusually small for an amphibole. Associated with the hastingsite are small patches of another hornblende, having a somewhat higher birefringence and a strong pleochroism, from olive-green to a pale ruddy or yellowish brown. It probably belongs to the arfvedsonite-katoforite series.

Sphene occurs in good lozenge-shaped crystals, which are almost invariably twinned. The pleochroism is from clove to grey. Sphene, and ilmenite in small grains, occur as inclusions in ægirine-augite and hastingsite. Small zircons and apatites, though few in number, are constant accessories, and occur as inclusions not only in the more abundant minerals but also in ilmenite. Tiny shreds of biotite, pleochroic from green to yellow, occur here and there as inclusions in orthoclase or microperthite.

The Mount Jombo (south-west of Mombasa) nepheline syenite[1] is strikingly similar to the Angola rock in structure and mineral composition, and both belong to the foyaite type as restricted by Brögger,[2] and bear a close resemblance to the type-rock of Foya.

Nepheline monchiquite.[3]—In the hand-specimen this rock has the characteristic aspect of a melanocratic rock, showing prismatic crystals of dark-brown hornblende up to half an inch in length embedded in a blue-grey aphanitic groundmass.

The minerals present, as seen under the microscope, are as follows, in order of abundance:—

Phenocrysts.	*Groundmass.*
Pyroxenes.	
Titaniferous augite.	
Ægirine-augite.	Nepheline.
Ægirine.	Analcime.
Augite.	Cancrinite.
Amphiboles.	Pyroxenes.
Barkevikite.	Amphiboles.
Arfvedsonite.	Apatite.
Hastingsite.	Ilmenite.
Sphene.	
Nepheline.	
Analcime.	

As indicated above, the *pyroxenes* form a connected series ranging from augite and titaniferous augite to ægirine-augite and pure ægirine. The largest crystals are idiomorphic (1×2 mm. in section), and exhibit a patchy colouring and zoning in various light tints of purple and green. The borders are well defined by bright-green ægirine, which is strongly pleochroic from blue-green to yellow-green. The

[1] J. W. Gregory, Q.J.G.S., lvi, 1900, p. 223.
[2] Brögger, *Zeit. Krist.*, xvi, p. 30, 1890.
[3] Pl. XI, Fig. 3.

interior is chiefly titaniferous augite, with pleochroic tints of yellow-green, brown-purple, and violet, and a maximum extinction of about 40 degrees. Between this and the bordering ægirine there is every gradation of ægirine-augite. Numerous small crystals of a deep purple colour also occur, but they are never free from a ragged border of ægirine. The latter, however, exists alone in long wisps and leaf-like growths. Still smaller crystals and tiny drop-like granules of grey-green augite free from pleochroism are sprinkled over the groundmass. The granules of augite are frequently aggregated together in groups and linear series of varying sizes.

The *amphiboles* form a similar series of the barkevikite–arfvedsonite–hastingsite type. The larger crystals are perfectly idiomorphic and sometimes show conspicuous zoning and twinning. The pleochroic scheme is—

$$\left.\begin{array}{lll} X \text{ near to } a & \ldots & \text{yellow-green} \\ Y = b & \ldots & \text{reddish-brown} \\ Z \text{ near to } c & \ldots & \text{purple-brown} \end{array}\right\} Z > Y > X$$

This agrees closely with the pleochroism of barkevikite from Barkevik[1] and Lugar.[2] The extinction angle $Z < c$ is about 10°, and the birefringence is nearly that of ordinary hornblende, offering in this respect a striking contrast to the other members of the amphibole series. Many of the crystals are bordered with blue-green arfvedsonite, some of which has a red or purple tint in one direction suggesting katoforite. Frequently titaniferous augite and barkevikite have grown together in parallel orientation, with numerous common inclusions of sphene and titanoferrite.

The smaller crystals are lozenge-shaped and possess a deeper colouring and a more intense pleochroism. Some of them are barkevikite, and others, unbordered, belong to arfvedsonite or katoforite. There are also small prisms of a green amphibole, which is identical in appearance and birefringence with the hastingsite of the nepheline syenite. The same mineral occurs in association with granular augite, forming an irregular border around the aggregates.

Sphene in good idiomorphic crystals is abundant, and is generally found clinging to or included in the pyroxenes and amphiboles. It is nearly colourless and therefore the pleochroism is barely perceptible.

Phenocrysts of *nepheline* are small though well formed, and are occasionally seen included in or penetrating the minerals already described. A very few clear spaces occupied by *analcime* may be seen, bordered by the coloured minerals.

These minerals, with small amounts of *ilmenite* and *apatite*, are embedded in a clear transparent groundmass. The absence of felspar in the latter was proved by staining. Radiating needles of nepheline and cancrinite can be readily distinguished, and between them is an isotropic base, which, like the crystals of analcime already mentioned, has a refractive index of about 1·49, and is almost certainly to be referred to that mineral. Further evidence in favour of this diagnosis is provided by the high content of combined water present in the rock.

[1] Brögger, *Zeit. Kryst.*, xvi, p. 412, 1890.
[2] Scott, *Min. Mag.*, xvii, p. 139, 1914.

The nature of the groundmass and the absence of felspar, in conjunction with the melanocratic habit of the rock, suggest that it should be placed among the *monchiquites*. It differs, however, from most monchiquites in having a somewhat lower proportion of the mafic minerals, and more vitally in the total absence of olivine. The naming of this rock raises the important question whether the presence or absence of olivine in a rock should affect its name and classificatory position. The division of igneous rocks on a silica saturation basis, as recently developed by Professor Shand,[1] seems to afford a sound basis for a more satisfactory mineralogical classification than has yet been proposed. In it rocks containing quartz, felspathoids, or olivine, would be sharply and naturally distinguished from any in which those critical minerals were not present. This distinction is already frequently made. Thus we have basalt and olivine basalt, tephrite and basanite, nephelinite and nepheline basalt (a better name for which would be olivine-nephelinite). The natural distinction based on the principle of saturation,[2] and actual precedent are therefore both against any extension of the existing term monchiquite to include rocks free from olivine. The difficulty may be evaded by defining monchiquite so that olivine shall not be an essential mineral, leaving the term olivine monchiquite for the original monchiquite of Hunter and Rosenbusch.[3] The only alternative appears to be that of proposing a new name. The term *Fourchite*,[4] which is already available, cannot be applied to the Angola rock, since it was given to a rock which contains 75 per cent of titaniferous augite and is conspicuously poor in alkalies. The multiplication of new names within a group like that of the monchiquites is greatly to be deprecated, and since there are already some other monchiquites which contain no olivine, and yet which are certainly not fourchites, it would be an innovation of considerable advantage to adopt the first suggestion and speak of monchiquites and of olivine monchiquites. Not only would precision be gained, but petrologists, already overburdened with varietal names, would be saved the influx of fresh ones as geological exploration continues. The principle is one which has been applied to many other groups of rocks, and which could be still further extended.

It is proposed, then, to classify monchiquitic rocks on a mineralogical basis as follows, the term monchiquite alone implying the presence of phenocrysts of pyroxene and amphibole in approximately equal proportions.

[1] GEOL. MAG., 1913, p. 508; 1914, p. 485. See also Scott, GEOL. MAG., 1914, p. 319; 1915, p. 160.

[2] The American Quantitative Classification fails to observe this principle, and the result is somewhat unfortunate, particularly in Order 5 (Q/F or L/F $< 1/7$) which includes rocks that may contain felspars, or felspars with quartz, or felspars with felspathoids.

[3] "Ueber Monchiquit, etc.": Tscherm. Min. Pet. Mit., xi, p. 445, 1890. See also Evans, Q.J.G.S., lvii, p. 38, 1901. Rosenbusch did not consider olivine to be an essential constituent (*Elemente der Gesteinslehre*, 1898, p. 233).

[4] Williams, Arkansas Geol. Surv. Ann. Rep., vol. ii, p. 107, 1890.

Olivine-free.	*Olivine-bearing.*
Nepheline monchiquite.	Nepheline olivine monchiquite.
Leucite monchiquite.	Leucite olivine monchiquite.
Biotite monchiquite (including ouchitite).	Biotite olivine monchiquite (including alnoïte).
Monchiquite.	Olivine monchiquite.
Pyroxene monchiquite (including fourchite).	Pyroxene olivine monchiquite.
Amphibole monchiquite.	Amphibole olivine monchiquite.

According to this nomenclature the rock under discussion would be called a *nepheline monchiquite.*

Chemical characters.—A chemical analysis of the work and a calculation of the norm gave the following results:—

Analysis.		*Molecular Proportions.*	*Norm.*		
SiO_2	46·06	·767	Orthoclase	17·79	Salic = 64·89
Al_2O_3	17·04	·167	Albite	19·39	
Fe_2O_3	4·01	·025	Anorthite	5·56	
FeO	4·51	·063	Nepheline	22·15	
MgO	3·15	·079	Diopside	16·85	Femic = 31·98
CaO	7·43	·132	Hypersthene	0·10	
Na_2O	7·13	·115	Magnetite	5·57	
K_2O	2·98	·032	Hæmatite	0·16	
H_2O +	3·32	—	Ilmenite	5·93	
H_2O −	0·70	—	Apatite	0·67	
CO_2	1·18	·027	Calcite	2·70	
TiO_2	3·15	·039	H_2O =	4·02	
P_2O_5	0·23	·002			
	100·89		Total	100·89	
Sp.gr.	2·76				

In the quantitative classification the analysis falls into the following divisions:—

Group II	Dosalane.
Order 6	Norgare.
Rang 2	Essexase.
Subrang 4	Essexose.

It is significant that most olivine monchiquites have the magmatic symbol III, 6, 2, 4 (analyses IV and V in the table below), and the nepheline monchiquite of Angola falls into Group II, as might be anticipated, on account of its lower proportion of femic to salic constituents. This difference is at once evident in thin section, and is also indicated chemically by the comparatively high percentages of alkalies and alumina and the low percentages of iron and magnesium. The analyses cited below also bring out the relation of the rock to the tinguaites (I) and the augitites (VI). The magmatic symbols clearly show that it lies midway between these somewhat extreme types. The olivine monchiquite of Cabo Frio, Brazil (V) is that which agrees most closely in chemical composition with the Angola variety, and the differences, especially between the contents of magnesium, iron, and aluminium oxides, are of the kind to be expected in comparing an olivine-bearing rock with one which is free from that mineral.

	I.	II.	III.	IV.	V.	VI.
SiO_2	55·02	53·28	46·06	45·17	46·48	42·25
Al_2O_3	20·42	16·38	17·04	14·78	16·16	16·26
Fe_2O_3	3·06	6·11	4·01	5·10	6·17	8·43
FeO	1·82	4·52	4·51	5·05	6·09	5·46
MgO	0·59	2·50	3·15	6·26	4·02	5·49
CaO	1·67	3·09	7·43	11·06	7·35	9·75
Na_2O	8·63	6·42	7·13	3·69	5·85	4·45
K_2O	5·38	4·18	2·98	2·73	3·08	1·92
H_2O + ...	} 2·77	3·52	3·32	} 3·40	4·27	2·43
H_2O −			0·70			
CO_2	—	—	1·18	—	0·45	—
TiO_2	—	—	3·15	—	0·99	2·52
P_2O_5	0·06	0·15	0·23	0·51	—	1·04
MnO	0·22	—	—	0·35	—	—
Totals . .	100·00	100·15	100·89	100·00	100·91	100·00
Magmatic Symbols and Names . .	(I) II, 6, 1, 4	II, 6, 1, 4	II, 6, 2, 4	III, 6, 2, 4	III, 6, 2, 4	III, 6, 3, 4
	Laurdalose.		Essexose.	Monchiquose.		Limburgose.

I. Average of fifteen analyses of *Tinguaite* after Daly, *Igneous Rocks*, 1914, p. 35.
II. *Ulrichite* (Camptonitic tinguaite). Dunedin, New Zealand. P. Marshall, Q.J.G.S., lxii, p. 397, 1906.
III. *Nepheline monchiquite.* 20 kilometres north-east of Senza do Itombe, Angola. Arthur Holmes, analyst.
IV. Average of sixteen analyses of *Olivine monchiquite*, after Daly, *Igneous Rocks*, 1914, p. 36.
V. *Olivine monchiquite.* Cabo Frio, Brazil. Hunter and Rosenbusch, *Min. pet. Mitth.*, xi, p. 445, 1890. M. Hunter, analyst.
VI. Average of six analyses of *Augitite*, after Daly, *Igneous Rocks*, 1914, p. 30.

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

NOTICES OF MEMOIRS.

A Discussion upon the Age of the Lower Tertiary Marine Rocks of Australia.[1]

By R. Bullen Newton, F.G.S.

The author referred briefly to the valuable palæontological work on the Australian Tertiaries carried out by such prominent authors as M'Coy, Ralph Tate, Dennant, Hall, Pritchard, etc., the majority of whom favoured an Eocene age for the Lower Tertiary deposits of Australia. The late G. F. Harris doubted the existence of such a formation, whilst M. Cossmann could see no relationships among the Lower Tertiary Opisthobranchs from Australia with Eocene forms from Europe.

Mr. F. Chapman, Palæontologist of the Melbourne Museum, has studied this subject, and proves very conclusively that those beds hitherto regarded as Eocene belong to the Miocene period—a view

[1] From Reports of the Eighty-fourth Meeting British Association for the Advancement of Science, Australia, 1914, published 1915, p. 375.

which the author fully supports. Mr. Chapman's work on the Batesford Limestone is important in this connexion, because of its containing *Lepidocyclina*, *Amphistegina*, and *Lithothamnium*—all of which characterize the Miocene beds of Europe, Java, Sumatra, Borneo, Formosa, etc.; the absence of nummulites in this limestone is against its age being either Eocene or Oligocene. These same limestones have also yielded Mollusca and Brachiopoda, as well as *Carcharodon megalodon*, which has its origin in Miocene rocks. The author was of opinion that the Lower Tertiary faunas of Australia presented in some cases a recent facies, in others a Miocene facies, with relationships to both European and South American species of that period. Among shells showing a resemblance to those of present-day seas, he mentioned *Cassis contusus*, *Siphonalia spatiosa*, *Typhis laciniatus*, all Tate's species, and mostly from the Muddy Creek deposits; and many more species might be quoted exhibiting a more or less recent appearance. Among fossil forms more particularly referred to was the *Aturia aturi*, var. *australis*, which has been recognized as coming from the Eocene of Australia. Although given a varietal name, this Cephalopod is not to be separated from the Miocene species of Europe known as *Aturia aturi*, and with this statement Mr. Crick, of the British Museum, thoroughly agrees. The species is found in many of the Australian deposits, as also in the Table Cape Beds of Tasmania, the Oamaru Beds of New Zealand, the Navidad Beds of Chili, South America, as also in the European Miocene. The more or less pointed rostrum of *Spirulirostra curta* illustrates an affinity with Miocene forms rather than with Eocene, which are more obtuse.

The large *Cypræas* described by M'Coy as Oligocene should more probably be regarded as Miocene, since they come from the Gellibrand River Beds, Muddy Creek deposits, etc., which also contain the *Aturia aturi* before mentioned. The Brachiopods of the Lower Tertiary deposits of Australia show a somewhat recent facies, a striking form being *Magellania garibaldiana*—a species occurring in the Mount Gambier Beds in association with the *Aturia aturi*.

Even before Mr. Chapman pointed out the Miocene characters of the Lower Tertiary deposits of Australia, Dr. Ortmann, of the United States, had published in 1902 his important monograph on *The Tertiary Deposits of Patagonia*, in which he compared the faunas of that continent with those of Australia. His researches were against the presence of Eocene in the Tertiaries of Australasia, and those beds hitherto recorded as such he identified as Miocene, and contemporaneous with the Pareora Beds of New Zealand, Navidad Series of Chili, and the Patagonian deposits, all of which showed unmistakable affinities with each other and favoured the view that a former connexion existed between South America and Australasia.

The term Oligocene among Australasian marine Tertiaries, the author was inclined to abandon because of the absence of *Nummulites*, their place being taken by *Amphistegina* and Lepidocycline forms of Foraminifera. Such rocks he would regard as Miocene. This would apply to the Balcombian and Janjukian Beds of Mornington, etc., and the older deposits of Muddy Creek and other localities.

REVIEWS.

I.—Geological Survey of Scotland.

The Geology of the Country round Beauly and Inverness. By J. Horne, LL.D., F.R.S., and L. W. Hinxman, B.A., F.R.S.E.; with contributions by B. N. Peach, LL.D., F.R.S., and E. H. Cunningham Craig, B.A. Memoirs of the Geological Survey, Scotland. Explanation of Sheet 83. H.M. Stationery Office, 1914. Price 2*s*.

THIS memoir has been issued in advance of the corresponding colour-printed map, the printing of which is delayed owing to pressure of work at the Ordnance Survey Office, occasioned by the European War. It is descriptive of the district from Inverness north to Strathpeffer, including Beauly and a part of the Black Isle, extending almost to Munlochy. Two main types of rock occur in this country: the Highland schists and metamorphic rocks form most of the western half of the Sheet, while the conglomerates and sandstones of the Orcadian or Middle Old Red Sandstone underlie the agricultural and more densely populated country near the coast.

The metamorphic rocks of the interior mountainous tract are not essentially different from those that occur in the Sheet to the west (82), of which a description was published in 1913. The Moine Gneisses of this part of Scotland are an old sedimentary group now represented by mica schists and quartzose biotite-granulites. With little variation they extend over wide areas; graphite schists and limestones are comparatively rare in this series, but at Rebeg, about 8 miles west-south-west of Inverness, a limestone occurs which is ascribed by Dr. Horne to the Moine rocks.

Another group of metamorphic rocks more varied in composition and character, as it included many types of orthogneiss and paragneiss, is represented by small outcrops in Glen Orrin, Glen Urquhart, and at Loch Luichart. These have attracted some attention, as among them occur kyanite-gneiss and white marble, unusual types of rock in eastern Inverness-shire. Glen Urquhart is known to mineralogists as a locality for interesting minerals. In the memoir they are assigned to the Lewisian Gneiss, but the evidence on which this conclusion is founded is not stated, as it was obtained actually in the district further west and has been given in the Memoirs on Glenelg and Central Ross. The Moine Gneisses are believed to rest unconformably on an irregular, highly eroded surface of the Lewisian Gneiss, but the interpretation of the junctions is rendered very obscure owing to complicated folding and metamorphism.

The Old Red Sandstone of the eastern part of the Sheet is very thick and at the same time very poor in organic remains. Dr. Peach estimates that on the north side of the Black Isle syncline there are 7,000 feet of conglomerates, sandstones, and shales. Two fish-beds with limestone nodules, like those found at Cromarty by Hugh Miller, occur in the Killen Burn, about 3 miles west of Avoch, and have yielded the Orcadian fishes *Coccosteus decipiens*, Ag., *Osteolepis macrolepidotus*, Ag., and *Gyroptychius microlepidotus*, Ag., with some plant-remains. A useful feature of the memoir is the account of the geology of the Strathpeffer district and the relation between the mineral waters and the fetid limestones and bituminous shales of the Old Red Sandstone of that locality. This was pointed out long ago by Hugh Miller, but his interesting speculations on the connexion between mineral waters and fossil fishes are not mentioned in the memoir.

One of the great structural lines of Scotland, the Great Glen fault, passes along the line of the Caledonian Canal, a little north of Inverness. Dr. Horne estimates that it has a downthrow to the south-east amounting to at least 6,000 feet, from its effects on the Middle Old Red Sandstone. Movement along this fault gave rise to the Inverness earthquake of 1901, of which Dr. Davison has remarked the similarity in character with the Japanese earthquake of 1891, indicating that mountain-building processes are not yet ended in the Scottish Highlands.

The glacial geology of the district presents no features of special interest, but the raised beaches of the Moray and Cromarty Firths are well known to geologists and geographers. Many passengers on the Highland Railway are familiar with the raised beaches of Kessock, which are illustrated in the memoir by a photographic plate. Visitors to Inverness must also be familiar with the conical gravel hill, known as Tomnahurich, that stands in the Ness Valley to the west of the town. It rises to a height of 200 feet, and was considered by Helland to be a moraine, but is regarded as of fluvio-glacial origin by the authors of the memoir.

II.—The Problem of Volcanism. By G. P. Iddings, Ph.B., Sc.D. pp. 273, with 86 figures, mostly photographic plates, Oro-Bathygraphical Chart of the World, coloured folding plate showing Recent and Tertiary volcanoes. Yale University Press; Oxford University Press; 1914. Price £1 1*s*. net.

THE treatment of the subject is frankly speculative. Once volcanic phenomena have been introduced by the citation of familiar examples, the question of the source of volcanic temperatures is raised. To meet this an account is given of nebular hypotheses, illustrated by fifteen beautiful photographs of nebulæ, fourteen of them from the Lick Observatory. The older hypotheses of Buffon, Kant, and Laplace are passed in review, and then a very sympathetic rendering is accorded to the contributions for which we are indebted to Chamberlin working, as that author tells us, in collaboration with Moulton. Chamberlin's contention is that the solar system has evolved from a spiral nebula, which in its turn may have originated in a tidal explosion of the sun during the near approach of some other star. It must be remembered that Laplace was writing in the dark when he pictured his great nebula. Nowadays improved telescopes coupled with photography enable us to discern such objects in ever increasing numbers. Among them spiral nebulæ, emitting a continuous spectrum, greatly preponderate, though variously shaped gaseous varieties are also found. Had Laplace been in possession of these facts, he, too, would probably have claimed a spiral ancestry for the solar system, and developed his mathematical treatment accordingly. It is not a little curious that Buffon should more nearly have anticipated Chamberlin's hypothesis, which latter, writes Iddings, "will be recognized as a refined expression of the conception of Buffon. The fundamental ideas are alike, the modern expression has had the advantage of a hundred and fifty years of astronomical discoveries and of improvements in the physical sciences." One of the features of the presentation of the hypothesis to-day is the claim that a spiral nebula can easily be conceived capable of meeting the dynamical requirements of a developing solar system in such matters as angular momentum, whereas a discoid gaseous nebula would find itself insolvent if faced with such liabilities.

According to Chamberlin the central mass of a spiral nebula represents a sun, and the cloudy knots distributed along the coiling arms are the nuclei of planets yet to be, while the nebulous material is the manna upon which these nuclei are to feed until they become perfected. Here, then, is the answer to the original question. The earth may have inherited a large hot nucleus, or on the other hand it may have grown from small beginnings by slow accretion in the cold. Iddings is of the opinion that the latter is the more likely alternative, and is insistent that we have no warrant to assume higher temperatures for the interior of the earth than those that are manifested at the surface through volcanic action, namely from 1,000° to 1,500° C. He supports this contention by pointing to the tidal rigidity of the earth, which he thinks suggestive of a restricted internal temperature. The heat of volcanic activity he attributes to condensation, radio-activity, and chemical re-arrangement; how much relatively should be assigned to each of these three factors he leaves to the future to decide. Joly's name is, of course, mentioned in connexion with radio-activity, but it is strange to read the partial truth that this investigator "considered it probable that radium exists throughout the earth"; it is not added that Joly is in essential agreement with Strutt in assuming a marked concentration in the more superficial portions. Further, is it a sufficient argument to say that "volcanic rocks do not contain any greater amount of radio-active matter than other rocks investigated, so that there cannot be any question of the possible local heating of igneous magmas by this means, as has been suggested by some geologists?" Surely in a uniformly radio-active crust, or even in one in which radio-activity fell off gradually downwards, one would confidently expect increasing temperature with increasing depth because of the relative thermal isolation at low levels. It is a simple conception that at a certain depth fusion supervenes, and that vulcanism is a complex convection phenomenon set in motion by radio-activity. But perhaps Iddings has safeguarded himself in this direction by the use of the word *local.*

Like Chamberlin, the author is a convinced adherent of the permanency of ocean-basins, and also of the principle of isostacy in its major applications. He takes an independent line in accounting for the origin of the great oceans, for he thinks that they overlie relatively large and dense planetismals, which have been welded with the substance of the growing earth. These dense accretions he recognizes not only through the sagging of the earth's surface above them, and the influence they exert upon the plumb-line, but also more directly through the products of their volcanoes. He maintains that there are two great provinces of igneous rocks, the Oceanic and the Continental respectively. What may be termed the average igneous rock of the former has a density of about 3·00, and of the latter 2·85. The Atlantic and Pacific hordes of various authors he dismisses as "highly artificial misnomers".

A difficulty which must occur to anyone in considering the application of Iddings' hypothesis, even in America, is the continental distribution of the Columbia River Basalts. This point is dealt with in advance as an example of the danger of loose petrographical nomenclature. Iddings takes two analyses, representative of large masses in the so-called basalt series, and recognizes in both a decidedly andesitic flavour. The treatment of the matter is too condensed to be satisfactory, and one wonders why the predominantly basic magmas (according to general belief) of Iceland and the Hebrides, of the Deccan, and of the Zambezi region, to take well-known examples, are not referred to. The Zambezi lavas are of great geological antiquity, and once we step back to consider such ancient products another lion is met with on the path. How is it that Scotland in Old Red Sandstone times furnished a typical continental suite of igneous rocks, and in New Red Sandstone times an equally typical oceanic suite? One might be tempted to argue that in this case an ocean basin had not been permanent, were it not that the lavas of New Red Sandstone age were erupted on a desert and many of their cracks and vesicles contemporaneously choked with millet-seed sand.

As might be expected from the foregoing, Iddings does not follow Daly in his speculations. For Iddings, the igneous rocks of a district afford a sample of the deeply buried foundation stones. During its upward progress the magma is frequently separated into more or less dissimilar fractions by differentiation, but is practically never polluted by assimilation.

In a short review it is impossible to follow our author further. A reader who enjoys a plunge into a sea of doubt is recommended to dip into the pages of this book. He is sure to be stimulated for a time, but, if in stature like the present writer, he will find it wearisome before long to be so continually beyond his depth.

One last point may be noticed. In the construction of a book of comprehensive aim it goes without saying that all available sources of information have not been consulted. Still, it is surprising to find that Heim's later writings have made so little impression that a 'double fold' is reproduced from the *Mechanismus* to illustrate Alpine structure.

E. B. Bailey.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *June* 9, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Accessory Minerals of the Granitic Rocks of the English Lake District." By R. H. Rastall, M.A., F.G.S., and W. H. Wilcockson, B.A.

The work described in this paper arose out of independent researches on the mineral composition of sediments, in which it became desirable to study the genesis of certain minerals. Preliminary investigations promised results of interest if the rocks of a whole district were examined, and for this purpose the Lake District was selected. The rocks here described are the granites of Skiddaw, Shap, and Eskdale, the microgranite of Threlkeld, and the granophyre of Buttermere and Ennerdale.

The material was pounded in a mortar, washed and panned, and the concentrate separated in bromoform after the removal of the magnetic portion.

The general results showed a well-marked variation of accessory minerals between the different intrusions, but a similarity between parts of the same intrusion, although the minerals of apophyses are not always the same as those of the main mass. No evidence is afforded for a genetic connexion between the different intrusions.

One of the most remarkable results obtained is the rarity of magnetite and the wide prevalence of pyrrhotite which was present in every sample examined, some thirty in number. Special attention was paid to the characteristics of the zircon crystals, which lent no support to the conclusions of Chrustchoff as to the occurrence of definite types in granite and gneissose rocks respectively. In parts of both the Skiddaw granite and the Threlkeld microgranite, anatase and brookite were found in abundance. It was not possible to determine their origin. Epidote is the characteristic mineral of the Ennerdale granophyre, while garnet is abundant at Threlkeld and Eskdale. The Eskdale granite also contains much tourmaline. The Shap granite is especially characterized by apatite and sphene.

It is concluded that descriptions of accessory minerals founded only on examination of rock-slices are inadequate and misleading; it is only by concentration that the rarer constituents can be satisfactorily determined.

2. "The Rocks of the Lyd Valley, above Lydford (Dartmoor)." By Frederic Philip Mennell, F.G.S.

The paper deals chiefly with a small area on the north-east of Dartmoor, though some of the conclusions are applicable to nearly all that part of the moor which lies north of the portion recently mapped by the Geological Survey. In the immediate neighbourhood of Lydford the progressive alteration of the Carboniferous rocks within the metamorphic aureole surrounding the granite is described in detail, and it is shown that they are consistently cordierite- and biotite-bearing, like those examined by Mr. Barrow at Holne. North of the altered limestone or 'calc-flinta' of Down-town, however, the type of alteration is entirely different, and leads to the inference that the beds are quite distinct. The change is of much more than local significance, as from this point all round the north of the moor, at least as far as South Zeal, there is no bed of any thickness containing cordierite, while chiastolite, white mica, and andalusite proper are characteristic. Coarse andalusite rock and altered shale, with remarkable skeleton crystals of chiastolite, are described from the Nodden quarries, together with other types of hornfels. It is clear that the beds occupying the northern part of the contact-zone belong to a definite series. There is strong evidence that the cover of the granite mass has a dome-like character, and that precisely the same stratigraphical horizon is in immediate contact with the granite all the way from Sourton to Drewsteignton.

The granite of Brator, not far from the best exposures of coarse cordierite-hornfels, is described. It is a biotite-bearing rock containing a little microcline, as well as orthoclase and oligoclase. It is rich in cordierite, recrystallized from sedimentary material absorbed into the magma. Several offshoots from the granite have been noted at various points along the Lyd. One near Nodden Gate is of interest, as containing topaz in remarkable abundance.

II.—Zoological Society of London.

1. *April* 13, 1915.—E. T. Newton, Esq., F.R.S., in the Chair.

Dr. A. Smith Woodward, F.R.S., F.Z.S., exhibited an anterior horn of a woolly rhinoceros (*Rhinoceros antiquitatis*), obtained for the British Museum, from frozen earth in Northern Siberia, by Mr. Bassett Digby. The horn must have measured originally nearly a metre along the curve of the anterior border. It has been cut and trimmed in places by the finders, but is sufficiently well preserved to show its laterally compressed shape and sharp posterior border.

Dr. Robert Broom, D.Sc., C.M.Z.S., read a paper on some new Carnivorous Therapsids in the Collection of the British Museum. Most of the specimens described have been for many years in the collection, but owing to their small size and imperfect condition they have not hitherto been recognized as new. Five species, belonging to four new genera, are Therocephalians. Two species, one of which belongs to a new genus, are Gorgonopsians, and one is a new species of a previously known Cynodont genus.

2. *May* 11, 1915.—Dr. A. Smith Woodward, F.R.S., V.P., in the Chair.

Dr. R. Broom, M.D., C.M.Z.S., read a paper on the Anomodont genera, *Pristerodon* and *Tropidostoma*.

Pristerodon, described by Huxley in 1868, is a very near ally of *Dicynodon*, differing mainly in having a series of molars which are smooth in front and have a series of denticulations behind. The males are tusked, the females without tusks. *Oudenodon raniceps* of Owen is a species of *Pristerodon*; while *Opisthoctenodon agilis*, Broom, and probably also *Opisthoctenodon brachyops*, Broom, are other species of *Pristerodon*.

In 1889 Seeley described two occiputs under the name *Dicynodon* *microtrema* and *Dicynodon* (*Tropidostoma*) *dunni*. As pointed out by Lydekker, these belong to the one species, *D. microtrema*.

CORRESPONDENCE.

ANDALUSITE AND CHIASTOLITE.

Sir,—I have read with much interest the note on the genesis of chiastolite in the May Number of the Geological Magazine.[1] Since I have had some considerable experience in the examination of rocks containing this mineral, may I be permitted to offer a few remarks on the subject? As is well known, chiastolite slate forms a conspicuous feature of the metamorphic aureole of the Skiddaw granite, especially in its outermost zones, while andalusite is likewise a common constituent of the more highly altered rocks nearer to the outcrop of the granite.

The author of the paper above alluded to states that inclusions of carbonaceous matter are essentially absent from andalusite: with this conclusion I cannot agree. My experience shows that the structures commonly described as chiastolite are, at any rate in the Skiddaw rocks, shimmer aggregates or pseudomorphs of colourless micaceous and chloritic minerals having the external form of crystals of andalusite and undoubtedly derived from them. This accounts for the inferior hardness and density of chiastolite alluded to by the author of the paper mentioned. In certain bands of the Skiddaw Slate Series there are numerous large and well-developed crystals of transparent and perfectly fresh andalusite, possessing all the characteristic optical properties of this mineral, with very conspicuous regularly arranged black inclusions: such crystals often show clearly the rose-pink pleochroism of andalusite, exactly as in the granitic rocks in which this mineral likewise occurs.

I venture to submit, therefore, that more evidence is required for the establishment of a real mineralogical distinction between these two forms, hitherto regarded as varieties of the same species.

R. H. Rastall.

Sedgwick Museum, Cambridge.

MISCELLANEOUS.

Erratum.—In the obituary notice of the late Mr. F. W. Millett some words have been unfortunately transposed, on p. 288 of our June Number; the first three lines should read: "Mr. F. W. Millett was chiefly known to geologists for his publications on the Foraminifera of the St. Erth Clays, and as an active worker on the more recent forms."

Addenda.—Please add the following magnifications to the illustrations in Mr. P. G. H. Boswell's paper on "The Petrology of the Suffolk Box-stones (Crag)" (June Number, pp. 250–9): Plate X, Fig. 1, × 26 diam.; Figs. 2–4, × 20 diam.; Text-fig. 1, p. 251, and Fig. 2, p. 252, × 20 diam.; Text-fig. 3*a*, p. 256, × 12 diam., and 3*b*, p. 256, × 25 diam.

[1] Geol. Mag., May, 1915, p. 224.

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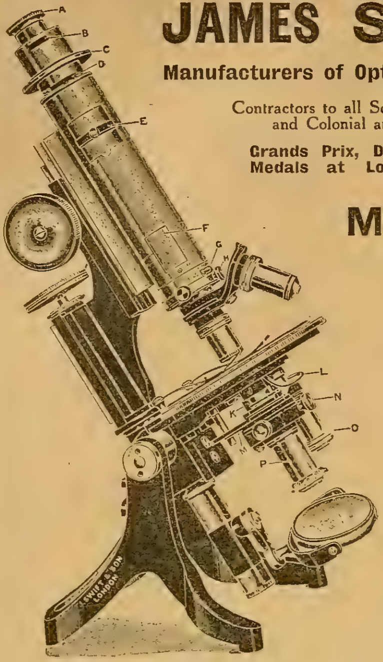

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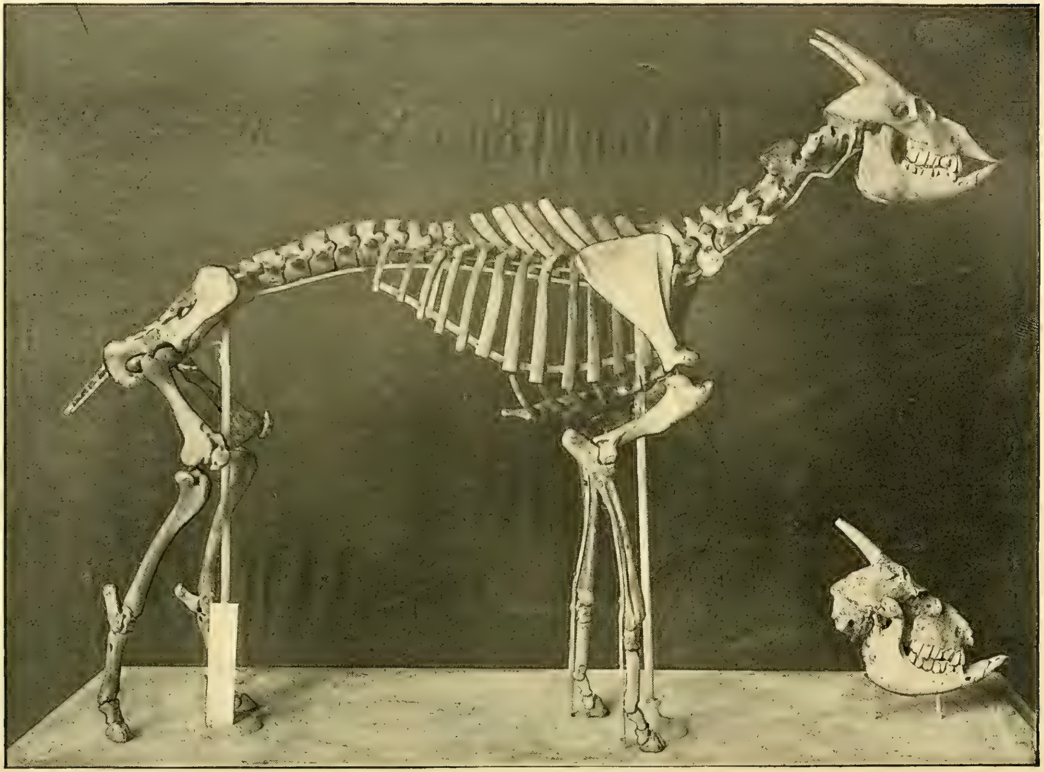

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Skeleton of *MYOTRAGUS BALEARICUS*, Bate (about $\frac{1}{7}$th nat. size), from Cave-deposits, Majorca.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. VIII.—AUGUST, 1915.

ORIGINAL ARTICLES.

I.—Note on a Mounted Skeleton of *Myotragus balearicus*, Bate.

By C. W. Andrews, D.Sc., F.R.S. (British Museum, Nat. Hist.).

(PLATE XII.)

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In the volume of this Magazine for the year 1909 (p. 385) Miss D. M. A. Bate gave a short account with some figures of a remarkably modified goat-like ruminant discovered in some remnants of cave-deposits in Majorca.[1] The chief peculiarities of this curious creature are that (1) instead of possessing the three pairs of incisors and pair of canines in the lower jaw, usual in the group, only the median pair of incisors remains, and these teeth are modified to form large permanently growing teeth like the incisors of a rodent; (2) the cannon bones on both the front and hind foot are extraordinarily shortened, this being especially marked in the former.

On a second expedition Miss Bate discovered that this remarkable form also occurred in Minorca, where it attained a somewhat larger size. In a recently published detailed description[2] of the skeleton the present writer has referred this large form to a distinct variety under the name *Myotragus balearicus*, var. *major*. Fortunately the collections made in Majorca were so large and complete that although in only a very few cases any bones of a single individual were found definitely associated, nevertheless it has been found possible to reconstruct the skeleton nearly completely, the only difficulty arising from the considerable individual variation in size occurring in the species. A figure of the mounted skeleton is shown on Plate XII.

In this reconstruction the skull and mandible are casts of the type-specimen, but the premaxillary region has been restored from another individual. The actual type skull and mandible are shown in the figure mounted on a separate stand. The vertebral column in part belongs to one individual, but has been completed with other vertebræ, and in some cases, especially in the caudal region, with plaster models. The ribs are mainly restorations. In the fore-limb only the scapula has been partly restored; all the rest is composed of actual bones, the collection including numerous examples of the

[1] An account of these caves was published by Miss Bate in this Magazine, 1914, p. 337.

[2] Phil. Trans., ser. B, 330, vol. ccvi, pp. 281–304 [pls. 19–22].

carpals and even of the tiny sesamoids. In the case of the hind-limb only the pelvis is restored.

The chief peculiarities of the skull are (1) the shortening of the face; (2) the position of the orbits, which look more upward and forward than usual; (3) the rigid attachment of the premaxillæ, the upper ends of which are firmly fixed between the maxillæ and nasals—in most related forms they do not reach the nasals, and consequently are weakly supported. As usual in the group the premaxillæ bear no teeth, at least in the adult. In one very young individual there is on one side a pit which may represent the alveolus of an evanescent tooth, though this is not certain. The mandible is relatively short and stout; the condyle, in spite of the peculiar modification of the incisors, is similar to that seen in Bovidæ, in which the normal arrangement of incisors and canines occurs.

As already mentioned the most remarkable character of this animal is the presence of a pair of large permanently growing incisors, the other incisors and canines being all suppressed, at least in the adult. These enlarged incisors have their anterior face covered with a thick coat of enamel, and in wear they together form a sharp cutting-edge, semicircular in outline. This edge must have worked against a hard pad on the premaxillæ, just as is the case with the incisors and canines of the normal Bovidæ.

The premolars are reduced to two in the upper, and in most cases only one in the lower jaw. The molars are remarkable for their extreme degree of hypsodonty, the roots of the first upper molar extending nearly up to the nasals, and its height being actually greater than that of m. 1 in a sheep of very much larger size. All the teeth seem to have been subjected to extremely hard wear.

The vertebral column presents no special peculiarities.

The fore-limb is chiefly remarkable for the shortness and stoutness of the humerus and metacarpus, while the radius and ulna are relatively slender bones. The shortening and antero-posterior compression of the metacarpus is far greater than that seen in any other member of the Bovidæ with the exception of the Takin (*Budorcas*), in which this bone is of strikingly similar form.

In the hind-limb the femur and metatarsus are much shortened, and here also great similarity with the corresponding bones of the Takin exists. One notable peculiarity is that in the adult the distal row of tarsals is fused to the metatarsus. In both fore and hind feet the vestiges of the lateral digits are much larger than usual, and the arrangement of the rather broad hoofs seems well adapted for climbing.

In the paper in the *Philosophical Transactions* above referred to, the various parts of the skeleton are compared with the corresponding bones in a number of other forms (e.g. the Rocky Mountain Goat (*Oreamnus*), the Goral (*Nemorhædus*), the Takin (*Budorcas*)), and from these comparisons it seems clear that *Myotragus* was a Rupicaprine antelope in which the feet, as in *Oreamnus* and *Budorcas*, were highly specialized for climbing on steep crags and screes, while the dentition has probably been modified for feeding on some very hard vegetable substance, as to the nature of which various suggestions have been made. It may have consisted of lichens, the hard fibrous stems of heath-like plants, or, perhaps, tough bark and woody tissue. Why the food should have been thus restricted is not clear; the climate cannot have been very cold, for the remains of a large land tortoise (*Testudo gymnesica*, Bate) have been found in the same deposits. On the other hand, there may have been conditions of aridity which led to the stunting of the vegetation. In any case the food must have been widely different from that of other members of the group in which no trace of such a modification of the dentition has occurred.

The skeleton has been mounted with great skill and care by Mr. L. T. Parsons, jun. Some approximate dimensions of the specimens as mounted (see Plate XII) are:—

	cm.	inches.
Greatest length	88	$34\frac{1}{2}$
Height to tip of horns	63	$24\frac{3}{4}$
Height to highest point of back . .	49	$19\frac{1}{4}$
Height to top of scapula . . .	$44\frac{1}{2}$	$17\frac{1}{2}$
Height to top of pelvis	43	17

II.—The Principle of Saturation in Petrography: A Reply.

By Professor S. J. Shand, D.Sc., F.G.S., Victoria College, Stellenbosch, South Africa.

In exercising a debater's right to reply to criticism, I shall be extremely brief. My contentions, in two essays on the above subject,[1] were as follows:—

1. That the classification of rocks by silica percentage is unsatisfactory, and that a more natural basis for classification is available in the degree of saturation of the constituent minerals.

My critic, Mr. Scott, has not expressed any opinion on this point of comparison.

2. That the field evidence is overwhelmingly favourable to the separation of the rock minerals into two groups, those of one group being stable in the presence of free silica under magmatic conditions, those of the other group unstable; and that such experimental work as has been done supports that separation.

Mr. Scott has not brought forward a single fact in refutation of this, but only a set of assumptions, considerations, probabilities, possibilities, and plausibilities. (I wonder if he realizes how much of his two communications consists of statements such as "this *might* happen", "the reaction *may be* appreciably reversible", "metasilicates *might* dissociate", "if, *as is probable*, fayalite dissociates", "*probable* origin of garnets", "*probable* instability of pyrope", "*if* it had crystallized", and so on?)

The recent work of O. Anderson [2] on the system anorthite-forsterite-silica shows afresh the instability of the forsterite-silica association. It is claimed, however, that "corroded crystals of olivine may be imbedded in reaction products or other minerals in such a way that they are protected against further reaction with the magma. In this

[1] Geol. Mag., November, 1913, p. 508, and November, 1914, p. 485.
[2] *Amer. Journ. Sci.*, April, 1915.

case we may find for example olivine and silica together in the same rock". Such a rock would simply be classed as an aberrant variety of the stable type towards which it tends.

3. That the criterion of degree of saturation would make the existing mineralogical system more definite than it is, while by no means barring the way to future improvements.

Mr. Scott replies that "petrological affinities would be obscured". I am tempted to ask whether some alleged affinities could possibly be made more obscure than they already are? Jesting apart, it is my opinion that most of the supposed affinities between loosely defined rock types are partly subjective, and that in any case they are incapable of quantitative treatment and must remain so until the rock names themselves are more precisely defined.

Mr. Scott also argues that the occurrence of solid solution may make it impossible to determine the degree of saturation of a rock and asserts that "many minerals can take up free silica . . . in solution". A truer statement would be that "a few minerals have been plausibly assumed to hold traces of silica in solid solution". None of the known forms of silica is isomorphous with any other rock mineral, and in the absence of isomorphism or chemical relationship the amount of solid solution that can take place is very small. Day and Shepherd[1] show that artificial pseudo-wollastonite (which, by the way, is pseudo-hexagonal and so nearer in form to quartz than any rock mineral is) may hold an amount which is "certainly less than 2 per cent" of silica in solution. It remains to be shown that any silica at all would be occluded if the magma contained another molecule, such as nepheline, which combines with silica. It is safe to say that the influence of solid solution in concealing traces of quartz or of unsaturated minerals is too insignificant to effect even the smallest subdivisions of a quantitative mineralogical classification.

4. That rock names which transgress the boundary between the saturated and the undersaturated rocks are inadequately defined and should be avoided. I presume that my critic disagrees with me on this point.

The only positive proposals which I have made towards the framework of a classification are as follows (my first paper, p. 513):—

Class I. Oversaturated rocks.
,, II. Saturated rocks.
,, III. Undersaturated rocks.
(*a*) Monad metals undersaturated.
(*b*) Dyad and triad metals undersaturated.
(*c*) Both monads and dyads undersaturated.

The scheme seems to me to offer a definite gain in significance and precision of nomenclature at the cost of a very small rearrangement of ideas. Subdivision of the classes will proceed according to mineral ratios, and this may be effected either in a purely arithmetical way, as is done by Iddings, or with regard to eutectic proportions and the order of crystallization.

In concluding, I should like to thank my critic for his comments; adverse criticism is always helpful in "clearing the air".

[1] Journ. Amer. Chem. Soc., 1906.

III.—On a New Plesiosaur from the Oxford Clay.

By William R. Smellie, M.A., B.Sc., Hunterian Museum, Glasgow University.

THIS Plesiosaur was collected from the Oxford Clay at Peterborough by A. N. Leeds, Esq., F.G.S., and was acquired for the Hunterian Museum, Glasgow University, by Professor J. W. Gregory. The specimen has many striking resemblances to *Cryptocleidus oxoniensis*, but detailed examination showed that it could not belong to that species, and the differences existing in the paddle, shoulder-girdle, number of vertebræ, and conditions of ossification are such that it cannot be retained in that genus as now defined. The paddle closely resembles that of *Tricleidus*, but the shoulder-girdle alone is sufficient to prevent the inclusion of the specimen in that genus. It seems advisable to create a new genus, and as it may be some time before a full description can be published a preliminary account is here given.

Apractocleidus, gen. nov.[1]

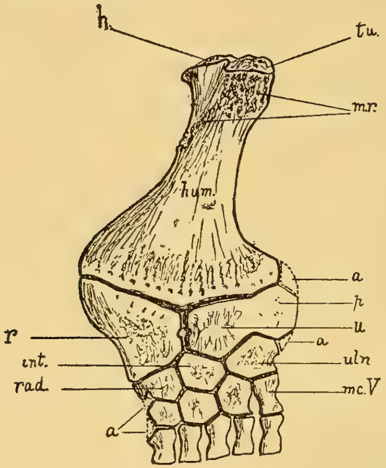
Plesiosaurs in which the neck is composed of about twenty-nine vertebræ of which the centra are wider than high and slightly higher than long. The oval articular ends are concave in the centre but convex near the margin. There are three pectoral vertebræ and twenty-three dorsals, or two pectorals and twenty-four dorsals. The shoulder-girdle is of Elasmosaurian type and so ossified as to form a very rigid structure. The coracoids are exceptionally broad and the postero-lateral processes are greatly produced. The dorsal rami of the scapulæ are widely extended in a similar fashion. The ventral ramus of the scapula is large, and in the adult the anterior portion has grown forward beyond the clavicles, which are very thin films of bone lying wholly within the visceral surface of the scapulæ. A rudimentary interclavicle may be present. In the mid-ventral line the scapulæ and the anterior parts of the coracoids impart a slightly carinate appearance to the shoulder-girdle. The humerus is greatly expanded distally and articulates with four elements. The pelvis is of great breadth, and the wide spread of the antero-external angles of the pubes taken in conjunction with the breadth of the shoulder-girdle indicates a genus of exceptionally broad build. The femur is slightly smaller and more slender than the humerus, and is not greatly expanded distally.

The genus is represented by one species, *Apractocleidus teretipes*, n.sp., the specific name (from *teres* = rubbed, well-chiselled, elegant, and *pes* = a foot) being descriptive of the symmetrical outline of the paddle.

In the type-specimen the parts preserved form a large portion of the skeleton of a fully adult individual, and the state of preservation of the bones is remarkably perfect even for Oxford Clay fossils. It differs from *Cryptocleidus oxoniensis* in the number rather than the

[1] The name *Apractocleidus*, meaning idle or functionless clavicle, has been adopted to accord with the names of the related genera *Tricleidus* and *Cryptocleidus*. For the suggestion of the name I am indebted to the Rev. Gavin Warnock, B.D.

form of the vertebræ, having twenty-nine cervicals, three pectorals, and twenty-three dorsals, while *Cryptocleidus* has thirty-two cervicals, three pectorals, and twenty-one dorsals. While the ossification is more complete than that found in larger and more massive specimens of *Cryptocleidus*, the posterior cervical ribs have remained free, a condition which may have evolved to mitigate the excessive rigidity which, as insisted on by Professor Williston,[1] must have existed in the thick part of the neck. The measurements given below and compared with *Cryptocleidus* will indicate some of the differences existing in the shoulder-girdle and pelvis. The humerus is like that



Proximal portion of left fore-paddle (outer side). (Type-specimen, V. 1091.) About $\frac{1}{10}$ nat. size. *a*, accessory ossicle (missing in original); *h*, head of humerus; *hum.* humerus; *int.* intermedium; *m.c. V.* fifth metacarpal; *m.r.* ridges for muscle insertion; *p*, pisiform (anchylosed to ulna); *r*, radius; *rad.* radiale; *tu.* tuberosity of humerus; *u*, ulna; *uln.* ulnare.

of *Cryptocleidus* in size and width of distal expansion, but the facets on the distal end are necessarily different to permit articulation with four elements in place of the two in *Cryptocleidus*. The epipodial bones are very similar to those of *Tricleidus* in shape as well as in number, and a well-marked foramen occurs between the radius and ulna. The hexagonal pisiform is anchylosed to the ulna, whereas it is free in *Tricleidus*. In some ways the specimen shows a curious blending of the characters of *Tricleidus* and *Cryptocleidus*, the paddle figured being a case in point, but in others it gives indications of being a more highly specialized type than either of those genera. The development of the shoulder-girdle has proceeded exactly on lines laid down by Dr. Andrews,[2] imparting increased rigidity to

[1] S. W. Williston, *Water Reptiles of the Past and Present*, 1914, pp. 80 and 91.

[2] C. W. Andrews, Ann. Mag. Nat. Hist. (6), vol. xv, p. 345, 1895.

the structure and rendering the clavicles functionless by increase in size of the ventral rami of the scapulæ. The coracoids are anchylosed to each other and to the fused scapulæ, while the glenoid is modified so as better to receive a directly forward thrust from the head of the humerus. Seeley[1] pointed out that perfect ossification and elongation of processes is coincident with higher organization and is more characteristic of Plesiosauria in the newer rocks.

In conclusion, I have to express my indebtedness to Dr. C. W. Andrews for providing me with every facility for studying the Leeds Collection at South Kensington, and my best thanks are due to Professor Gregory for the interest he has taken in the work and for the indispensable guidance I have received from him.

Some dimensions (in centimetres) of the type-specimen (V. 1091) are given below, together with some dimensions of specimens of *Cryptocleidus* for comparison.

	Atlas and Axis.	Fourth Cervical.
Length of centrum in mid-ventral line	4·4	2·8
Width of posterior end of centrum	2·9	3·6
Height of posterior end of centrum	2·4	2·9
Height to top of neural spine	5·5	7·4
	V. 1091.	R. 2616.[2]
Greatest length of combined scapula and coracoid .	60·0	66·5
Width of united coracoids between outer ends of postero-external angles	62·5	57·1
		R. 2860.[3]
Greatest length of pubis	20·8	25·3
Greatest width of pubis	35·0	30·5
Width between antero-external angles of the two pubes	66·0	55·0
Humerus: Length	32·0	28·5
Width of distal expansion . . .	24·6	21·4
Femur: Length	30·1	27·0
Width of distal expansion	19·5	16·0

IV.—Alpine, Lowland, and Jura Lakes in Switzerland.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

In the preceding paper[4] I dealt with the five principal and zonal sub-Alpine lake basins in relation to their age and origin, while the object of the present one is to group and consider the more prominent of the smaller Swiss lakes which I have had repeatedly occasion to visit and examine. Omitting the high altitude lakes, such as the Merjelen and the Engadine Lakes, which I described in previous papers,[5] as also the hundreds of lakelets disseminated throughout

[1] Seeley, Q.J.G.S., vol. xxx, pp. 449, 1874; Proc. Roy. Soc., vol. li, p. 149, 1892.

[2] Andrews, B. M. Cat., *Marine Reptiles of the Oxford Clay*, pt. i, pp. 195–6, 1901.

[3] Op. cit., pp. 190–1.

[4] Geol. Mag., 1915, pp. 215–24.

[5] Ibid., 1896, p. 97, and 1893, p. 222.

Switzerland, I shall confine myself to those lake basins from whose glacial or hydrographic features definite conclusions may be drawn. The illustrations (Sheets Nos. 1–4, Figs. I–X), having to cover the large area of Central and Northern Switzerland, are necessarily drawn to a small scale, but all particulars may be gleaned from the Swiss 1 : 25,000 contour map, to which the metric altitudes and dimensions in this paper correspond.

I. Lakes with Gorge Exit Channels.

1. *Lake Klöntal* (Sheet No. 1, Fig. I), one of the most picturesque though least known of the smaller Alpine lakes, lies in a Cretaceous basin between the Glarnisch and Wiggis massifs at altitude 826 metres, about 80 metres above Glarus in the Linth Valley. The present lake has shrunk from its original length of 6 km. to 2·5 km., its average width being 500 metres and its greatest depth 31 metres. Its two main affluents are the Klön and the Rosematter streams, the latter of which rises in one of the Glarnisch glaciers. Its exit is by a steep and narrow gorge channel through which the Löntsch, in a series of cascades about 2 km. in length, reaches the Linth Valley and discharges into the Linth at Nettstall, a short distance below Glarus, at altitude 440 metres, the average fall in the total length of 3 km. being thus 1 in 8. The lake has probably reached its present greatest depth by solution; the hanging valley in which it lies is of special interest in that its altitude indicates the former level of the Linth Valley floor, which, like that of the Zurich Valley in the same drainage area at the time of the Deckenschotter being deposited on Utliberg after the first glaciation, was subsequently eroded to its present level, about 400 metres lower.

2. *Lake Aegeri* (Sheet No. 1, Fig. I) occupies a basin in the Molasse area at the western base of Rossberg, at altitude 725 metres. Its present length of 5 km. is barely one-half of its former extent, while its average width is now 1 km. and its greatest depth 80 metres. As a storage basin it is of great industrial importance to Canton Zug. It derives special interest from the moraine wall which, beginning at its lower end, extends down to the Zug Valley. After overflowing this wall at a much higher level than now, the Lorze cut through it, as well as through the older glacial deposits below, down to the Molasse, thus forming the Lorze ravine, 6 km. in length at a fall of 1 in 20. Beyond this moraine and gravel bank fully 100 metres in depth, the Lorze built up an extensive cone in the direction of its flow towards the Reuss, of which it was then a direct affluent. The present Lake Aegeri, as a moraine-barred basin with a steep exit channel, was obviously formed during the recession of the Reuss Glacier, which, in its last advance, impinged upon Rigi and Rossberg, and then flowed round them in three branches.

3. *Ancient Sihl and Waeggi Lakes* (Sheet No. 1, Fig. I).—These two basins, although their lakes are extinct, may be grouped with the preceding ones as having moraine bars and steep exit channels, and as such may be termed "ancient glacier lakes in overflow valleys". As is seen from the sketch-plan, they lie in the Molasse area on the

left of Lake Zurich, at altitudes 840 and 800 metres, or about 400 metres above that lake, their length being 10 and 5 km. and their mean width 2 and 1 km. respectively. Both valleys were choked by the Linth Glacier advancing more or less at right angles through the Zurich Valley, and the lakes thus formed existed until during the recession of the glacier they overflowed the moraine walls,[1] and the Sihl eroded for itself an entirely new course through moraine and Molasse parallel to Lake Zurich, while the Waeggi-Aa found its old way again direct to that lake. The floors of both basins sloping considerably towards their exits, where erosion was, moreover, very active, the lakes gradually emptied themselves through their exit channels, which have an average fall of 1 in 40 and 1 in 30 respectively, as shown in the diagrams (Sheet No. 1, Fig. III[2]). The altitudes of the exits of both basins, which are practically hanging valleys about 400 metres above the present Lake Zurich, point to the same conclusion as that arrived at in relation to the altitude of the Klöntal Valley.

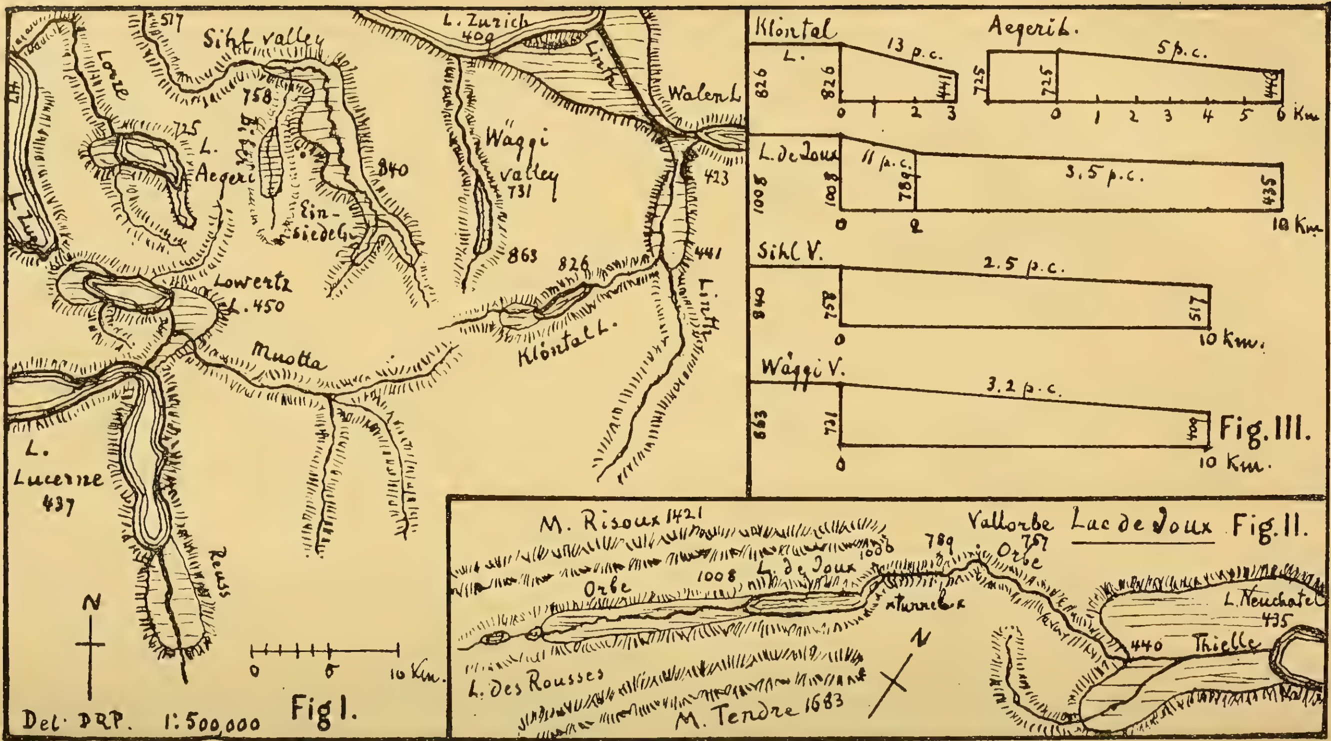
4. *Lac de Joux* (Sheet No. 1, Fig. II), well known for its winter sports, occupies, at 1,008 metres altitude, a Cretaceous basin between the two ridges of Mont Risoux and Mont Tendre, the former of which marks the crest-line of the Jura. As shown in the sketch-plan, the lake formerly extended fully 15 km. or double its present length of 7·5 km., higher up the valley, practically to the Lac des Rousser, from which issues its principal affluent the Orbe. The average width of the present lake is 1 km., and its greatest depth 34 metres. At its lower end it connects with a small outer lake, Lac Brenets, practically an outflow regulation and storage tank, at the end of which the Orbe plunges into a funnel or 'entonnoir', characteristic of the Jura, whence it issues 2 km. below at altitude 789 metres, viz. at a fall of 1 in 10, and then winds in a steep ravine past Vallorbe through the Jura until it discharges into the Yverdun Canal at the head of Lake Neuchatel. Lac de Joux owes its existence to one of the numerous shallow depressions in the Jura terraces parallel to the axis of the chain, and its gradual deepening to the action of solution in its Cretaceous bed, while its abnormal shrinkage is due to evaporation and percolation. Fortunately, the entonnoir, being at its exit instead of a fissure in its floor, saved the overflow valley from drying up. The lake and the River Orbe constitute important power factors in the industrial development of that part of the Jura, as do Lake Klöntal and Lake Aegeri in their respective areas.

II. Lakes with Moraine or Fluviatile Bars.

In this group I have comprised the smaller lakes which, with the one exception of Lake Sarnen, lie in the Molasse formation and at altitudes between 435 and 540 metres. For the sake of brevity their dimensions are given in the following table (p. 350):—

[1] An illustration of the moraine wall cut by the Sihl at Schindelleggi will be found in my paper, Q.J.G.S., vol. lii, p. 570, 1896.

[2] Both these ancient lakes are, in the near future, to be reconstituted for hydro-electric power purposes by valley bars, the Sihl basin alone being estimated to yield 60,000 horse-power.



FIGS. I–III.—Sheet No. 1. Lowland and Jura Lakes.

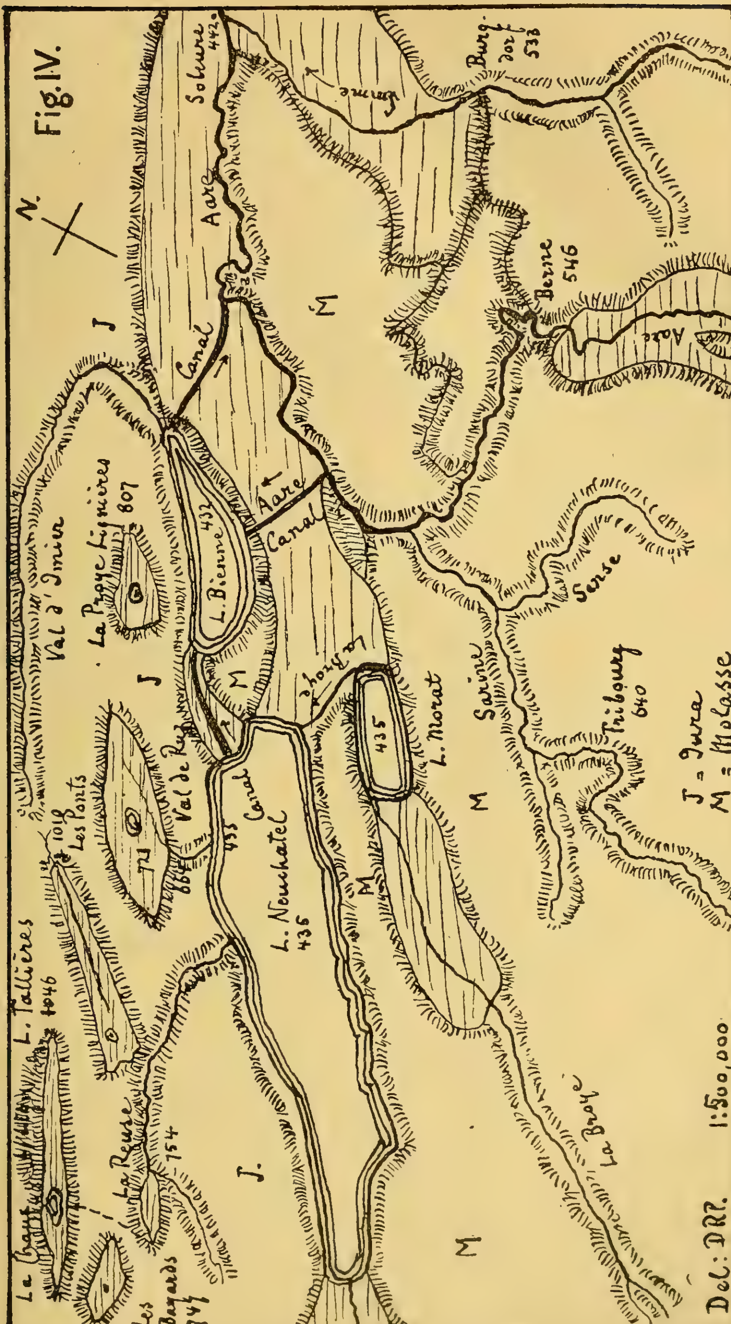


FIG. IV.—Sheet No. 2. The Neuchatel Jura (extinct Jura lakes).

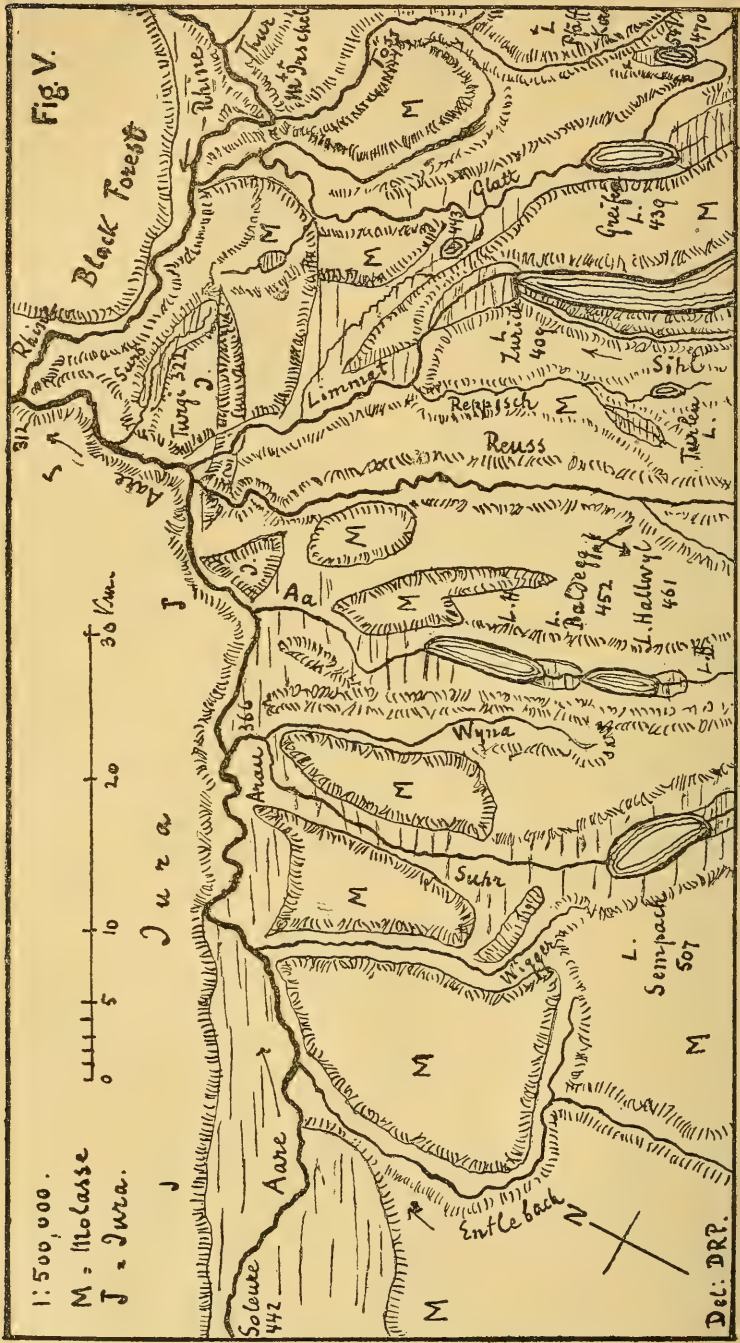
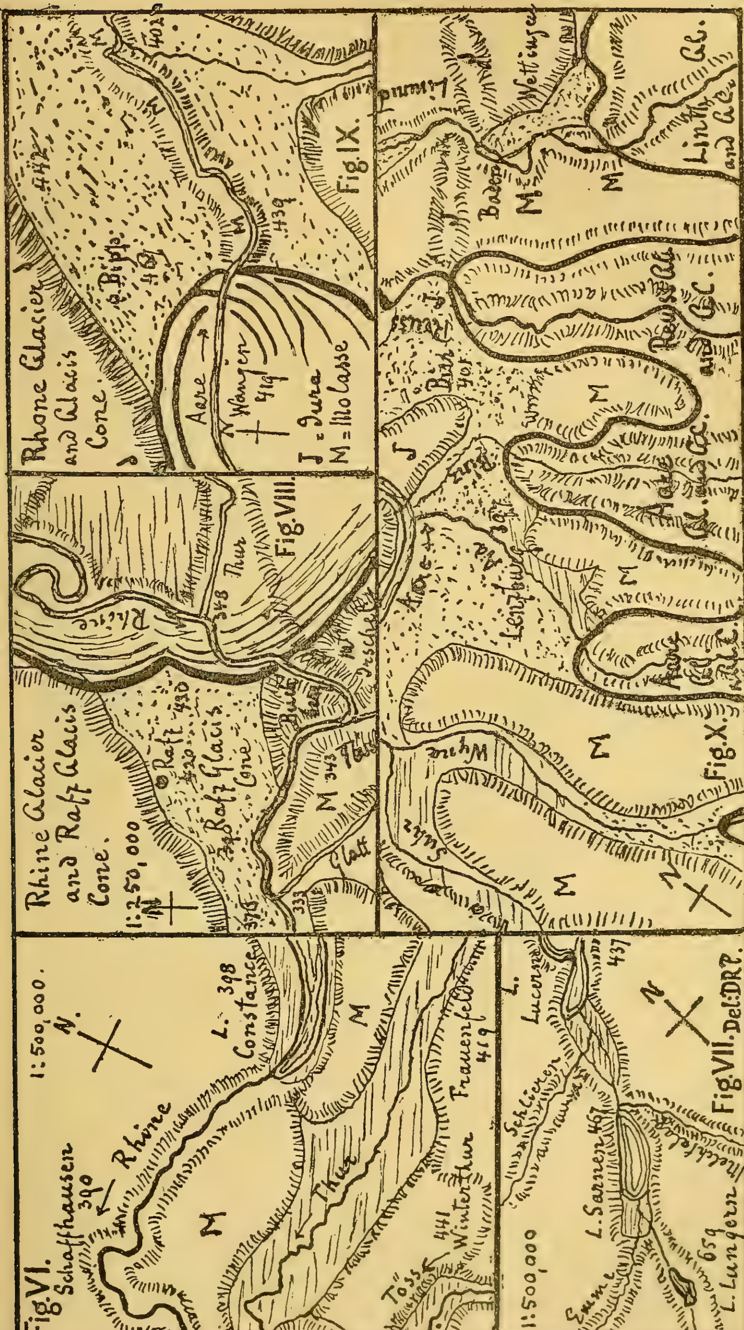


FIG. V.—Sheet No. 3. Lakes with Moraine or Fluviatile Bars.



Figs. VI–X.—Sheet No. 4.

Lake.	Altitude.	Length.	Mean Width.	Greatest Depth.	In Drainage Area of
	metres.	km.	km.	metres.	
1. Pfäffikon	541	2·5	1	35	Rhine
Greifensee	439	6·5	1·5	33	,,
2. Baldegg	466	5	1	66	Aare
Hallwil	452	10	1	45	,,
Sempach	507	8	2	83	,,
3. Lowertz	450	3	0·8	11	Reuss
Sarnen	467	5·5	1·2	10	,,
4. Morat	435	10	3	51	Aare

1. *Lakes Pfäffikon and Greifensee* (Sheet No. 3, Fig. V) lie in shallow depressions of the Glatt Valley area and are twin lakes, being fed by the Aa as principal affluent, which, on emerging from Greifensee, takes the name of Glatt. Both have lost much of their former size, Greifensee having shrunk to less than half its former extent. They are both banked by moraine, and are the remnants of lakes formed during the recession of the Linth Glacier, which, probably augmented by a branch of the Rhine Glacier, filled the Glatt Valley and advanced to within a few miles of the Rhine at Eglisau. The Glatt Valley presents a noteworthy feature in that, after the Linth had been deflected back to the Zurich Basin after the last glaciation, it became a dried-up valley whose floor lies now from 30 to 50 metres higher than that of Lake Zurich. The same phenomenon characterizes the neighbouring valleys of the Rhine drainage area, such as the Thur and Töss Valleys, whose great width is altogether disproportionate to the size of the present affluents of the Rhine, and which must have been eroded by rivers of much larger volume.

2. *Lakes Baldegg, Hallwil, and Sempach* (Sheet No. 3, Fig. V).—The first two of these are twin lakes, being fed by the same river, the Aa, while Lake Sempach, in a neighbouring parallel valley, has for its principal affluent the Suhr, both rivers being tributaries of the Aare. The three lakes present precisely similar features, the first two occupying shallow basins in the Seetal Valley, while the third lies in a similar depression of the Suhr Valley. All three have shrunk to two-thirds of their former size, and the valleys, as also the contiguous parallel ones of the Wyna and Wigger, are disproportionally wide in relation to the small rivers. Like the valleys of the Rhine affluents, they must have been eroded by rivers of much larger volume and erosive force, or may have been occupied for a long period by shallow lacustrine expanses; possibly, here, as there, the indirect action of ice by pressure also contributed to give them the flat-dome lines of the Molasse formation. All three lakes lie in the area of the Aare Glacier and are banked by moraine; hence they must have been formed during the retreat of that glacier.

3. *Lakes Lowertz and Sarnen* (Sheet No. 1, Fig. I, and Sheet No. 4, Fig. VII) properly form part of the Lake Lucerne system into which they drain. Lake Lowertz, a remnant of the Reuss when the whole, or part of it, flowed along the northern base of Rigi, now discharges,

by its exit stream, into the Muotta, which formed the big alluvial cone of Ibach above Brunnen, and thereby banked Lake Lowertz; indeed, this cone was probably the primary cause of the Reuss being deflected to its present course. The lake, greatly reduced in size, is at a level 11 metres above that of Lake Lucerne. Lake Sarnen, which is close to the Brünig railway and 37 metres higher than the Alpnach basin of Lake Lucerne, into which it drains, was, like Lake Lowertz, banked by fluviatile alluvia, that is, by the cones of the Schlieren and Melchtal-Aa torrents. The small Lake Lungern, 192 metres above Lake Sarnen, now drains into the latter.

4. *Lake Morat* (Sheet No. 2, Fig. IV) is an offshoot of Lake Neuchatel and connected with the latter by the Broye, which is also its principal feeder. As is seen from the sketch-plan, it formerly extended, at its upper end, to double its present length, while at its lower end it formed part of the Lake Neuchatel and Lake Bienne system, which intercommunicated with the great lacustrine expanse formed by the River Aare. It was obviously the alluvia of this river, reinforced by the Sarine, which banked and separated Lake Morat and Lake Neuchatel, and also barred Lake Bienne. Connected with the Aare was also the great lacustrine expanse in the valley of the Emme between Burgdorf and Soleure (Fig. IV), which valley is even at the present day subject to partial submergence by periodical floods.[1]

III. Extinct Jura Lakes.

The Neuchatel Jura is remarkable for a number of interesting examples of extinct or quasi-extinct lakes and dried-up basins, of which the principal ones are shown in Sheet No. 2, Fig. IV. The one at the highest altitude—1,046 metres—is the La Chaux basin, 15 km. in length and about 2 km. in width, of which the small Lac Taillières—1,038 metres altitude—is the only lacustrine remnant. The latter, about 10 metres deep, has no visible outlet, but it is reputed to have an underground connexion with the River Reuss which issues at St. Sulpice, at altitude 754 or 284 metres lower, the vertical distance being 5 km., and the rate of fall, therefore, 1 in 2. It is, however, probable that the Reuss derives its copious volume from several underground sources.[2] Another extinct basin is that of Les Ponts, near Chaux de Fonds, altitude 1,010 metres, about 10 km. in length and 2 km. wide, which has a lakelet without exit. The same applies to the basin of La Praye, near Lignières, at altitude 807, 4 km. in length and 1 km. wide, with an exitless pool, and precisely similar is the large basin of Val de Ruz above Lake Neuchatel at altitude 721 metres, 8 km. long and 3 km. wide, except that this basin has an exit by a torrent, which, through the steep gorges of the Seyon, drains into the lake. The history of all these basins is the same. Formed

[1] Incidentally it may be mentioned that Lake Morat, like Lake Pfäffikon, is noted for its remains of lake-dwellings.

[2] An interesting case of subterranean torrents so characteristic of the Jura formation occurred a few years ago in the course of the works of the new tunnel from Frasne to Vallorbe (Simplon route), when a torrent rising in Mont d'Or and discharging normally by an underground passage near Pontarlier, suddenly burst through the tunnel near Vallorbe and discharged into the Orbe.

in shallow Jurassic depressions slowly deepened by solution, the water found an underground exit, the level of the lake was gradually lowered, and its floor, drying up, was covered with vegetable matter, leaving a pool in the deepest part, and reducing the basin to peat moss.[1]

IV. False Lake Floors.

By this unusual term I refer to certain extensive alluvia which have all the appearance of having been deposited as lake floors in standing water, viz. at a dead level, but which are extensive, flat glacis cones formed in front of the moraine walls of glaciers, while the latter, having reached the limit of their advance, remained stationary. As already shown in the preceding paper, these glacis cones, which have an average inclination of 1 in 200, were deposited by the streams flowing round and escaping under the moraine wall, until the glacier began to retreat, when the main stream overflowed the moraine wall and, more frequently than not, found its way outside the glacis cone and then eroded its own bed through the solid rock. Sheet No. 4, Figs. VIII–X, show the more important of these cones formed in front of the terminal moraines of the five principal glaciers at the extreme limits of the last glaciation. The two most extensive cones[2] are those of the Rhone Glacier in the Aare Valley below Soleure and Wangen, about 10 km. in length, and of the Rhine Glacier below Schaffhausen of about the same length, while the less extensive ones are those of the Aare, Ress, and Linth Glaciers. The Aare circumvented the Rhone Glacier cone by overflowing at the margin of the glacier and cutting its bed through the Molasse at a depth now 50 metres below the level of the cone (Sheet No. 4, Fig. IX), while the Rhine, by a similar process, eroded its new Molasse bed through the saddle between Mount Irschel and Buchberg (Sheet No. 4, Fig. VIII), where the present level of the river is nearly 80 metres lower than the glacis cone. Similarly, the Reuss broke through the Jura spur at Mellingen, leaving the glacis cone on its left, and the Limmat eroded the Molasse at Wettingen, leaving the glacis cone on its right. Thus the glacis cones were left high and dry, with all the outward appearance of lake valley floors.

Conclusion.

1. Whatever lakes or lacustrine expanses may have existed in the areas described during interglacial periods previous to the last glaciation, it is obvious that the present smaller lakes banked by moraine can, in their original larger extent, have been formed only during the retreat of the glaciers after the last general advance of the latter, that is, like the five principal lake basins considered in the preceding paper, towards the end of the Ice Age, while the smaller

[1] According to Dr. H. Walter (in a paper in 1896 on "Terrestrial Surface Changes in Canton, Zurich"), within the last 250 years since 1668, out of 149 lakelets shown in Gyger's authentic lake-map of Northern Switzerland of that time, no less than 73 dried up and were obliterated and 16 were largely reduced in size.

[2] The term delta does not apply to these cones, as they were not formed in standing water.

lakes banked by fluviatile bars are clearly post-Glacial. On the other hand, Lake Klöntal and Lac de Joux lie in old pre-Glacial valleys, of which that of the former was no doubt filled with or choked by the Glarnisch Glacier, upon whose retreat the lake was formed. Lakes Neuchatel and Bienne occupy the trough of the contact line of the Jura and the Molasse formations, and, lying in the zone of the Rhone Glacier,[1] were probably formed during the retreat of the latter; but both, as well as Lake Morat, were subsequently banked by the post-Glacial alluvia of the Aare.

2. The remarkable shrinkage of all the smaller lakes, compared with the much larger areas covered by them at the time of their formation, cannot be due to want of precipitation, for neither north nor south of the Alps is there any marked diminution of the annual rainfall. The cause must therefore be sought in gradually increasing loss of water by evaporation and percolation. Increased solar heat during dry summers causes increased melting of the glaciers and superabundance of water in the lakes and lowlands, which is, however, generally followed by a shortage of supply in winter, so that the increased evaporation of the lakes in summer is not compensated by additional volume of water in winter.[2] Still greater is the loss by percolation through the dry soil of the drainage areas and the permeable rock strata below, by which, as shown by the dried-up basins of the Jura and certain quasi-dried up valleys in the lowlands, large masses of water are abstracted from the surface and circulate underground. The gradual shrinkage not only of the smaller lakes but of the five principal zonal lake basins as the great hydraulic storage and regulation reservoirs of Switzerland would be a disquieting phenomenon were it not that the areas dried up are so much land reclaimed, and that the shrinkage itself may be but a cycle in the evolution and lapse of time.

V.—On the Formation of the River Tyne Drainage Area.

By Edward Merrick, M.Sc.

(*Concluded from the July Number, p. 304.*)

D. The Earth-Movements considered Stratigraphically.

An important factor in the formation of this drainage area as above outlined is the movement of the rocks after they had been reduced to a surface comparable with a peneplain. These movements are now reviewed to see if any assumptions have been made which are probably incorrect from stratigraphical evidence.

1. The Stublick Dyke was supposed to be later than the formation of the junction plane, else it could not affect the contours as indicated on the north of itself and the Tyne.

[1] The boulders of Rhone Valley (Valaiz) origin on Mt. Chaumont above Neuchatel, at an altitude of 1,220 metres or 785 metres above the lake, were deposited by the Rhine Glacier of the maximum glaciation.

[2] Of this frequent shortage in winter, practical proof is afforded by the fact that most, if not all the large Swiss hydro-electric power installations have added reserve steam-power to their hydro-turbines to meet that shortage.

2. The Cross Fell Anticline was supposed to be later, or partly later, than the formation of the junction plane, else it could not have affected the contours as indicated on the north, east, and south.

3. The Pennine Fault was supposed to be later than the formation of the junction plane, else it could not have affected the contours as indicated on the east and west.

4. The *throw* of the Pennine Fault since the formation of this plane was supposed to be measured by the throw of the contour-lines upon its surface.

5. Any earlier faulting will alter the amount of throw of the geological deposits.

6. The conjecture was also made that the movements in this area might follow pre-existing lines of weakness and motion.

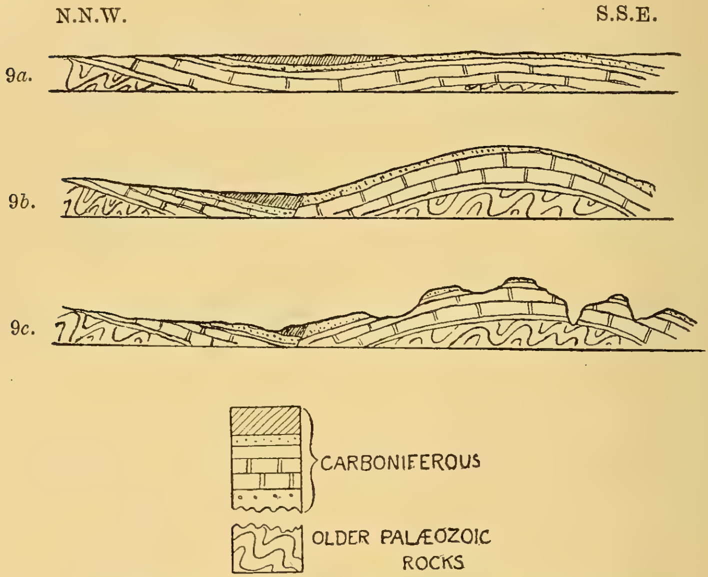


FIG. 9. Simplified north to south section along the Cross Fell escarpment.
,, 9*a*. Condition late in the Carboniferous period.
,, 9*b*. The peneplain buckled, altering land-levels and levels of rock outcrop.
,, 9*c*. Erosion since the buckling.

These hypotheses, if correct, necessitate the existence of—

1. Pre-Mesozoic tilting or folding and planing, producing a plain of marine denudation, peneplain, or surface of planation. This rock surface, when covered by later deposits, would become a junction plane or even a plane of unconformity.

2. Mesozoic or later folding and faulting producing an undulating junction plane.

3. Contemporary erosion which on continuation during later periods has produced the present-day hills and valleys (Fig. 9).

Stratigraphical Evidence.

1. In this area post-Carboniferous and post-Permian movements are known to have given changing directions of strike and dip to the rocks. Some of these movements are known to be pre-Permian, but owing to the absence of Mesozoic rocks it is not known if the post-Permian movements are also post-Mesozoic ones. Pre-Permian planing is proved by the unconformity between the Carboniferous and Permian formations, both in this and neighbouring areas. It is proved in South Durham by borings at Bradbury Carrs and Elstob, while at Conscliff the Magnesian Limestone is seen to rest upon Millstone Grit. The Yellow Sands are so irregular that the occurrence of the Magnesian Limestone upon the Millstone Grit cannot be held as proving either overlap or erosion of the Yellow Sands. Permian erosion is proved in the Eden Valley by the presence in the Brockrams of Carboniferous Limestone pebbles which are regarded as coming from the Cross Fell escarpment, thereby implying the pre-existence of the Pennine Fault. The latest erosion of the Tyne area can only be returned as post-Permian from the stratigraphical evidence of the solid rocks.

2. Evidence of these movements is found in the neighbouring areas of the Rivers Eden and Tees, where the land sank below sea-level, then rose again with some covering of Liassic deposits that now exhibit signs of disturbance. The Pennine Fault, by disturbing the Triassic sandstones, is an example of Mesozoic or later faulting which follows an older line of weakness.

In describing the main valley and the collecting areas on its flanks, the difference in surface levels was attributed to the Stublick Dyke and the Cross Fell Anticline producing undulations of a rock surface composed of strata with a common trend. If such were actually the case, then the highest elevations reached by the different strata on its flanks should vary in the same manner as the difference in surface levels of the rock surface. Such, indeed, is found to be the case. In a paper entitled "A New Flora of Northumberland and Durham", by Messrs. J. G. Baker and G. R. Tate, 1868, there is a geological introduction by Mr. G. Tate. In this paper it is mentioned that the rocks attain different elevations on the two banks of the Tyne, but no explanation is given for this. There is also a botanical map founded upon the river drainage, but nothing is said about the origin of the watersheds. The highest recorded outcrop of the Permian formation in Northumberland is that of the yellow sands (now obscured) at Closing or Clousden Hill, Killingworth, near the 200 foot contour-line.

Dr. D. Woolacott states that the highest point on the Permian escarpment in Durham is at Warden Law, which is 646 feet high. From this height about 120 feet of sand and gravel must be deducted, leaving 526 feet for the height of the rock surface. Other exposures are near the 500 foot contour.

It is noticeable that the older rocks in the west are more elevated than the younger ones in the east, yet it does not necessarily follow that they form an older part of the Tyne drainage area.

TABLE IV.

ROCK ELEVATIONS IN FEET.

Strata.	Northumberland.	Durham and Cumberland.	Difference in Level.
Magnesian Limestone .	Marden (100)	Warden Law (526)	426
Yellow Sands . .	Killingworth (200)		
Coal-measures . .	Heddon Laws (500)	Pontop Pike (1,034)	534
Millstone Grit . .	Heddon Laws (500)	Cross Fell (2,930)	2,430

Though the outcrop of the Millstone Grit has been arched up some 2,500 feet higher at Cross Fell than in the Tyne Valley, yet the change in level of the land surface and dip of the strata is so gradual that it is similar to the passage of horizontal strata into a monoclinal fold which gradually breaks into a fault along the Tyne Valley. On the other hand, when examining the Geological Survey maps of the older rocks forming the inlier below Cross Fell, it is observed that they are bounded on the north by normal faults throwing north, and on the south by normal faults throwing south.

The Carboniferous rocks on the top of this inlier are very slightly disturbed, being almost horizontal, while those in the synclines flanking it (as near Haltwhistle and Fourstones) are rolling and associated with short and sharp anticlinal and synclinal folds. These disturbed rocks lie at a lower elevation than the surface of the inlier, giving it the appearance of a buttress against which they have been pressed; but as they occur some miles north of the inlier, this appearance may be deceptive. The above description would almost fit the Craven area if Ingleborough were put for Cross Fell, and the other place-names also changed.

The drainage system of the Tyne has been described above as due to the denudation of a composite plane of rock. Because the close connexion between the field structure and drainage supports this view, this river system is therefore not regarded as one superimposed upon it by the denudation of a younger deposit now completely removed. Yet if this area were ever covered by a deposit of fairly uniform thickness, laid upon this rock surface as an unconformity, the resulting drainage would still be much the same as it is now, provided that this young deposit were older than the earth movements already described.

The denudation of the area is so closely related to the outcrops of its rocks (nearly all of which belong to the younger Palæozoic period) that it has the appearance of continuous action during the later periods, especially so as the most elevated area is most eroded. That this may not be the case is seen on comparing it with a younger area with greater denudation.

A suitable area for such comparison is the Weald, where post-Cretaceous movements arched the Chalk into an anticline now denuded. When a line of correlation was drawn as an anticline connecting the two escarpments, its height above the present surface was termed the "Geological Elevation" of the Chalk by Mr. W. Hopkins. This is a height of some 2,500 feet, and by a happy chance the same height that the Millstone Grit on Cross Fell has been arched above its outcrop in the Tyne Valley. In the Weald the line of geological elevation may not represent the actual position of the rocks in time past, but in Tynedale the geological elevation and former position of the Millstone Grit are identical, for the fell tops are capped by it, proving that it once crossed the valleys between them. Denudation in the Weald has cut to a greater depth than in the Tyne area, and as it occurred there in post-Cretaceous times the denudation here may not have acted continuously since the Permian period; in fact, it may be quite young. On the other hand, Tynedale may be regarded as containing better weather-resisting rocks than the Weald. Some time will have to elapse before Cross Fell is replaced by a river and the Tyne Valley becomes a synclinal mountain (Fig. 9*c*).

A noticeable feature of the Tyne between St. Peter's and Hebburn is that it flows between two rocky banks for a little distance; elsewhere, though rock be exposed in its bed or on one bank, the other bank is generally composed of superficial deposits. A little further east the Tyne passes the outlier of the Permian escarpment on Tynemouth cliffs and then joins the sea.

The Ouseburn in Jesmond Dene and the Burn at Newburn have this rocky feature also, but not the Team nor the Derwent. The rocky and narrow valleys are cut nearly at right angles to the strike of the strata, while the other and wider valleys are nearly parallel with the strike. These rocky streams are also at a less depth below the restored surface of the land than the other streams. This nearness to the original surface brings about the following effects (which are independent of the recent changes in sea-level):—

1. An example of stream action found in the collecting areas of its tributaries.
2. An appearance of youth through less depth of erosion.
3. An appearance of age, because the Tyne is tidal here and at its base-level of erosion (for the present moment).

This part of the river bears comparison with the rivers from the Weald cutting through the Chalk escarpment and then running either into an area of Tertiary rocks or the sea.

Coincidence with old lines of weakness, etc.

The following examples show the relationship between the present land surface and older features:—

1. The Pennine Fault through being pre-Permian and post-Triassic is an old line of weakness and motion. It has produced part of the western watershed to the Tyne.
2. The present-day watershed from Cross Fell to Cleadon lies above the pre-Carboniferous ridge which was inferred by Mr. J. G. Goodchild and given in position in Mr. Jukes-Browne's *Physical Geology*.
3. The Carboniferous strata below the Millstone Grit in the Tyne Valley are collectively thicker than those on the southern watershed.
4. That this watershed follows the general direction of the junction plane between the Coal-measures and the Permian strata is shown in a section drawn by Messrs. Wood, Taylor, and Marley from Hownes Gill to Monkwearmouth. There is also a slight increase of slope of the junction plane near the coast.

TABLE V.

Slope of the South Watershed.	*Slope of the Unconformity.*
Cross Fell to Muggleswick, 77 feet per mile.	
Muggleswick to Cleadon, 36 feet per mile.	Painshaw Hill to Monkwearmouth, 133 feet per mile.
Cleadon coast out to sea on the sea-bottom, 20 feet per mile.	

5. Having made allusion to the parallelism of the younger deposits with the junction plane below them, I may next point out the effects of the forces producing the present-day land surface upon the position of the deposits now being formed.

That the contour-lines of the sea-floor have been produced by these forces is illustrated in the following table, in which it is observed that the contours near the coast are close together, while the deeper ones are wider apart, and it is most prominent that the deeper soundings are between two and three miles nearer inshore off the mouth of the Tyne than elsewhere. This points to the continuation of the Tyne trough seawards, and the spacing of the contour-lines is similar to that along the southern watershed.

The average slope of the sea-floor off the mouth of the Tyne—23 feet per mile—is greater than the probable slope of the rock surface of the main valley before denudation—17 to 18 feet per mile.

TABLE VI.

Locality.	25 feet.	50 feet.	75 feet.	100 feet.	150 feet.	200 feet.
	m.	m.	m.	m.	m.	m.
The Rockers, Blyth . .	0·61	1·35	1·72	2·48	5·4	10·8
St. Mary's Island . .	0·3	0·6	1·18	1·6	4·43	10·1
Sharpness Point (River Tyne Outlet) . . .	0·26	0·7	1·2	1·8	4·5	8·65
Lizard Point . . .	0·2	0·4	0·82	1·62	3·65	8·65
Holey Rock (Roca) . .	0·45	1·0	1·9	2·88	4·35	9·5
Salterfen Rocks . .	0·25	1·5	2·5	3·25	4·85	+10
Feather Bed Rocks . .	0·4	1·0	2·5	3·4	6·5	+ 8·5

The distances in miles are taken from the high-water mark at the base of the cliffs at the rocky points of the mainland. The figures are obtained from the 1 in. Ordnance Maps. All these rocky points do not lie in one line as a base, but the first four are nearly in line, and also the last three in another line.

6. The contours off the mouth of the Tees are seen to be produced by the forces which made the Cleveland Hills (Fig. 10).

E. Relationship to other Drainage Areas.

The superficial deposits in this area prove that the land stood recently at a higher elevation, and that the present tidal part was excavated to a considerable depth which was above the sea-level of that period. This elevation would naturally be accompanied by an increase of coastal land; the greater the amount of land and elevation the greater the probability that the streams now running into the sea would run into the continuation of the Tyne over the extra country. This would cause the present watersheds to be deflected so as to include these drainage areas, but these deflections could only affect the south and north watersheds. The west one would remain unaltered from this cause.

It may be mentioned here that several authorities believe that the western watershed has been altered by tributaries from the Eden capturing the Irthing. The western watershed, through being part of a long one, has a feature shared by many other rivers. This long watershed separates the streams flowing into the North Sea from those to the Atlantic, Irish Sea, and English Channel. The continuation of this watershed in Europe separates the rivers flowing to the North Sea from those to the Mediterranean Sea, and ultimately joins the watershed between the Atlantic and Pacific Oceans. A geological feature of this watershed is that from the North to the South of England it lies upon rocks becoming younger and younger, as also do the strata on the coast, the result being that the more south a drainage area is, the younger it appears from the deposits contained in it.

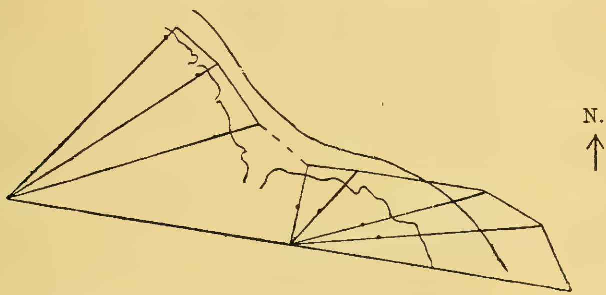


Fig. 10.—Soundings (diagrammatic) off the Mouth of the Tees following the sea-level (0 feet) contour of the peneplains from Cross Fell (Palæozoic rocks) and the Cleveland Hills (Mesozoic rocks).

The continental continuation of this watershed enters the Alpine region, which was a centre of great mechanical energy. Is it an allowable inference that movements contemporary with the formation of the Alps would follow older lines of weakness to an increasing degree as the distance from this centre of activity increased, and ultimately with complete coincidence, where young deposits are absent, that the age of these movements would consequently be dated further back?

At the present time the Tyne area can be considered as part of a larger unit which includes all rivers receiving tributaries from Cross Fell or which act as tributaries to them. This unit resolves itself into the Eden and its tributaries on the west, and the Tees, Wear, and Tyne on the east. To these the Blyth, Wansbeck, and Coquet might be added.

The southern watershed to this system runs from the Lake District to the Cleveland Hills, and is generally associated with anticlines.

A somewhat similar watershed is the northern one from Loch Ryan to the coast north of the Coquet.

FIG. 11.—Map of the eastern half of the Cross Fell drainage area. Dimensions of Tyne area as given by Mr. T. J. Taylor in 1851:

	Sq. miles.
North Tyne and Reidwater	473
South Tyne to confluence with North Tyne .	267
Tyne below confluence	402
Total . . .	1142

The rivers associated with these watersheds show some similarity in their courses:—

	NORTH WATERSHED.	SOUTH WATERSHED.
N. Slope.	River Tweed.	River Tees.
	River Clyde.	River Eden.
	Firth of Forth.	Tyne Valley.
	(Nothing.)	River Eamont, Ullswater.
	River Doon and Loch Doon.	River Derwent and L. Bassenthwaite.
	Forth and Clyde Canal.	Proposed N/C. and Carlisle Canal.
S. Slope.	River Dee and Loch Ken.	River Leven and Lake Windermere.
	Solway Firth.	Morcambe Bay.
	River Tyne Catchment.	Humber Catchment.

VI.—The Bekinkinite of Barshaw (Renfrewshire), and the Associated Rocks.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Lecturer in Mineralogy and Petrology, University of Glasgow.

(*Concluded from the July Number, p. 311.*)

Chemical and Mineralogical Composition.

THE chemical composition of the Barshaw bekinkinite has been determined by Mr. E. G. Radley, of the Geological Survey (Table I). In the Glasgow Memoir (pp. 134–5) Mr. Bailey points out the general similarity of this analysis to those of picrite, nepheline-basalt, and Hillhouse basalt, from the Lower Carboniferous of the Midland Valley of Scotland, and also to the type bekinkinites of Madagascar. The Barshaw rock, however, is distinctly richer in lime and alumina than the other Scottish rocks, indicating a greater richness in the anorthite molecule. This is well brought out in the calculation of the mineral composition from the chemical analysis (see later). The ultrabasic end-differentiates of the Scottish analcite rocks tend either to be enriched in the bisilicate minerals or in olivine. The former type includes the Barshaw bekinkinite, the picrites, and some Ayrshire theralites; the latter includes peridotites, kylites, and certain nepheline- and analcite-basalts. Chemically the bisilicate type tends to be rich in lime and ferrous iron, and comparatively poor in magnesia, with, for the silica percentage, a rather large amount of alkalies. The olivinic types are rich in magnesia, with low silica and alkalies. In the American Quantitative Classification the Barshaw bekinkinite falls into the subrang III, 6 . 4 . 5 (named 'papenoose' by Lacroix), whereas the bekinkinites of Madagascar fall into the neighbouring subrangs III, 6 . 3 . 4 (limburgose) and III, 6 . 3 . 5 (unnamed). The majority of the Scottish analcite rocks fall into limburgose (III, 6 . 3 . 4), monchiquose (III, 6 . 2 . 4), or camptonose (III, 5 . 3 . 4), subrangs whose clear relationships are shown by their numerical symbols.

The chemical composition of lugarite is illustrated in Table I by analyses of the Barshaw and Lugar rocks, both of which are here published for the first time. It is not intended to discuss these analyses fully in this place, as a full discussion will appear in a detailed paper on the Lugar sill. It will be seen that the analyses are unique in British petrography, and as far as is yet known in the world. In the American Quantitative Classification, the type-rock from Lugar falls into II, 7 . 1 . 5, a hitherto unoccupied and unnamed subrang next to lujavrose (II, 7 . 1 . 4). The latter contains the lujavrites (eudialyte - nepheline - syenites) of the Kola Peninsula, Finland, and related rocks from Greenland, Portugal, and the Transvaal,[1] all of which are much richer in potash than lugarite. The Barshaw lugarite falls into II, 6 . 1 . 5, but in a position transitional to II, 7 . 1 . 5.

The quantitative mineral composition of the rocks has been obtained in two ways, by means of the Rosiwal micrometric method, and by

[1] J. P. Iddings, *Igneous Rocks*, vol. ii, p. 279, 1913.

calculation from the chemical analyses. In making the Rosiwal measurements it was not found possible to treat the leucocratic minerals separately, as their boundaries were so indefinite and obscured by alteration. Hence they were measured as a group of colourless minerals (groundmass) as against the easily measured coloured minerals. To arrive at the mass proportions of the constituents from the data thus obtained, it was necessary to know the specific gravity of the groundmass. This was obtained by calculation, knowing the specific gravity of the rock as a whole, and the specific gravities and volume proportions of the coloured minerals. These measurements do not give the complete mineral composition, but they provide information as to the relative quantities of the coloured minerals, and the ratio between the light (felsic) and dark (mafic) constituents.

TABLE I.

	I.	II.	III.
SiO_2	40·87	46·29	46·58
TiO_2	2·85	2·37	·53
Al_2O_3	16·23	17·47	15·25
Fe_2O_3	1·31	2·24	7·58
FeO	7·37	7·07	4·70
MgO	9·83	2·10	2·30
CaO	11·13	5·82	4·68
Na_2O	2·78	8·69	8·93
K_2O	·53	1·47	1·70
H_2O (above 105 C.) .	4·28	5·12	4·53
H_2O (at 105 C.) . .	1·35	·69	1·91
P_2O_5	·52	·70	1·04
MnO	·64	·28	·10
(Co Ni) O	·06	—	—
Li_2O	? tr.	—	—
CO_2	·38	none	none
FeS_2	·21	—	—
BaO	—	·09	—
	100·34	100·40	99·83

I. Bekinkinite,[1] III, (5) 6 . 4 . (4) 5 (Papenoose). Barshaw, near Paisley. Analyst, E. G. Radley. Quoted from *Geology of the Glasgow District* (Mem. Geol. Surv.), 1911, p. 134.

II. Lugarite, II, (6) 7 . 1 . (4) 5. Lugar, Ayrshire. Analyst, A. Scott, M.A., B.Sc. Analysis published for the first time.

III. Lugarite, II, 6 (7) . 1 . (4) 5. Barshaw, near Paisley. Analyst, A. Scott. Analysis published for the first time.

In order to calculate the quantitative mineral composition from the chemical analysis of a rock it is necessary to know the exact chemical composition of the constituent minerals. These data,

[1] The figures following the name of the rock show the exact position of the rock in the American Quantitative Classification. See Cross, Iddings, Pirsson, and Washington, *Journ. Geol.*, xx, pp. 550–61, 1912.

especially in regard to the complex pyroxenes, amphiboles, and micas, are rarely available. It is generally necessary to make certain assumptions as to the chemical composition or amount of one or more minerals present in the rock, and to test the correctness of these assumptions by the congruity of the result with what is known or reasonably conjectured as to the quantitative mineral composition of the rock. In the present case, for example, the exact chemical composition of the olivine, titanaugite, and barkevikite present in the rocks is not known. There is available, however, an analysis of barkevikite [1] from the lugarite of Lugar, by Mr. A. Scott, and it is a reasonable assumption, considering the similarity of the rocks, that the barkevikite of the Barshaw rock has a composition similar to that of the Lugar mineral. There is also an analysis of titanaugite [2]

TABLE II.

MODES OBTAINED BY ROSIWAL MICROMETRIC ANALYSIS.

	I.	II.	III.	IV.	V.	VI.
Titanaugite	23·2	14·5	12·4	—	21·7	29·8
Ægirine	—	—	—	3·8	—	—
Barkevikite	13·5	24·4	26·0	12·5	17·2	14·7
Olivine (serpentinized)	1·3	—	—	—	—	18·6
Iron-ores	5·8	7·0	4·2	·6	5·0	4·9
Pyrite	—	—	—	—	—	·2
Apatite	2·3	2·2	2·4	2·5	3·1	1·1
Plagioclase			9·8			
Orthoclase	53·9	51·9	16·8	80·6	53·0	30·7
Nepheline			17·3			
Analcite			11·1			

Summation 100 in each case.

I. Lugarite, variety 1. Barshaw.
II. Lugarite, variety 2. Barshaw.
III. Lugarite, variety 2. Barshaw. Duplicate measurement.
IV. Lugarite, variety 3. Barshaw.
V. Lugarite, type-rock from Lugar sill.
VI. Bekinkinite. Barshaw.

from the porphyritic essexite of Crawfordjohn, Lanarkshire, also made by Mr. Scott. The optical properties of this mineral are very similar to those of the titanaugite of the Barshaw rocks, and the chemical composition of the Crawfordjohn essexite cannot be so very different from that of the Barshaw bekinkinite. Hence it is legitimate, at least in a first trial, to use the Crawfordjohn analysis in calculating the composition of the Barshaw rock. Actually this analysis gave a good result for the Barshaw lugarite, but not for the bekinkinite.

[1] A. Scott, "Barkevikite from Lugar": Min. Mag., xvii, p. 140, 1914.

[2] SiO_2, 42·65 ; TiO_2, 4·17 ; Al_2O_3, 7·47 ; Fe_2O_3, 4·15 ; FeO, 9·98 ; MgO, 11·70 ; CaO, 13·75 ; Na_2O, 4·90 ; K_2O, tr. ; P_2O_5, 1·38 ; H_2O + ·04 ; MnO, tr. ; total, 100·19. The Al_2O_3 contains some thoria, probably present as inclusions of a thoria-bearing mineral. The P_2O_5 probably represents inclusions of apatite.

It was also found necessary to fix the amount of olivine in the bekinkinite. It was assumed that olivine was present in the same amount (18·5 per cent) as it occurred in the norm, calculated according to the methods of the American Quantitative Classification. This assumption was much strengthened by the fact that the amount of olivine (serpentinized) in the rock, measured by the Rosiwal method, came to 18·6 per cent. In the calculation of lugarite it was found necessary to fix the amount of analcite present. This was taken as 12 per cent, since rough measurements (micrometric) of the amount of analcite present in two varieties of the Barshaw lugarite gave 11·1 and 13·8 per cent respectively.

The various compositions, as given by the two methods, are set out in Tables II and III.

The duplicate measurement of variety 2 of lugarite (Table II, col. III) was made a year earlier than that of col. II, and on fewer slides. Notwithstanding, the agreement between the two is sufficiently good.

TABLE III.

MODES OBTAINED BY CALCULATION FROM THE CHEMICAL ANALYSES.

	I.	II.	III.
Titanaugite . .	11·9	16·5	9·1
Ægirine . . .	—	—	6·0
Barkevikite . .	16·5	10·2	13·3
Olivine . . .	18·5	18·5	1·7
Ilmenite . . .	3·6	4·0	—
Magnetite . .	—	—	6·3
Pyrite . . .	·2	·2	—
Apatite . . .	1·3	1·3	2·4
Orthoclase . .	1·1	1·1	8·9
Albite . . .	9·4	10·5	24·4
Anorthite . .	32·5	29·2	—
Nepheline . .	—	3·1	10·4
Analcite . . .	—	—	12·0
Water, Alteration Products, etc. .	6·0	6·0	5·4
	101·0	100·6	99·9

I. Bekinkinite. Barshaw.
II. Bekinkinite. Barshaw. Second calculation.
III. Lugarite. Barshaw.

Analyses of titanaugite from Crawfordjohn, and of barkevikite from Lugar, were used in Nos. I and III; in No. II an analysis of augite from monchiquite of Serra de Tingua, Brazil (analysis *q* of table xii, Cross, Iddings, Pirsson, and Washington, *Quantitative Classification of Igneous Rocks*, 1902) was used in place of the Crawfordjohn titanaugite.

Comparing Tables II and III, it is evident that the mineral composition of the bekinkinite, as obtained by calculation from the chemical analysis, does not agree well with the micrometric analysis. The greatest difference is in the relative amounts of the light and dark minerals. The chemical analysis gives a much more leucocratic type than does the micrometric analysis, and, moreover, provides no nepheline or analcite. These discrepancies may arise from three causes: the assumptions made as to the chemical composition of the constituent minerals may not be correct; the chemical analysis may be incorrect; or the rock analysed by the Survey may not be identical with the one investigated in this paper. In connexion with the first-mentioned, a calculation of the mineral composition utilizing the analysis of a Brazilian augite gave better results in so far as it was possible to obtain a little nepheline (No. II, Table III), but the relative amounts of the light and dark constituents remain much the same as before. The second hypothesis may be dismissed as improbable in view of the high quality of the Survey analyses. It is more probable that, assuming the accuracy of the analyses, the discrepancy between the results obtained by the two methods arises from the fact that the rock analysed by the Survey evidently contained little or no nepheline, and was rich in the anorthite molecule, thus differing from the type described in this paper. The amount of lime and alumina in the analysis is much in excess of that required for the bisilicate minerals, and could only go into anorthite.

For the lugarite, however, there is a satisfactory agreement between the results of the two methods of analysis. In the calculation of mineral composition from the chemical analysis it was assumed that ægirine and olivine were present in the amounts fixed by those of the norm, and that analcite totalled 12 per cent. The result of the calculation shows that these assumptions were justified. The calculated mineral composition agrees best with varieties 1 and 2 (Nos. I, II, and III of Table II). In the one case there is an excess of pyroxene, in the other an excess of barkevikite in the micrometric analysis as compared with the quantities of these minerals in the calculated mineral composition. It is probable, however, that the rock analysed contained both types of lugarite, and that the chemical analysis therefore represents a mixture of these two types. The quantitative relations of titanaugite and barkevikite vary considerably, even within the limits of a single thin section.

There are one or two minor discrepancies. For example, no anorthite can be calculated out of the chemical analysis on the assumptions made, although the anorthite molecule must be present in small amount. Moreover, the percentage of TiO_2 in the analysis is too small to allow any ilmenite to be calculated after titanaugite and barkevikite have been satisfied in this constituent. As ilmenite is undoubtedly present, the above minerals must either be poorer in titania than assumed, or the analysis must be defective in this particular. In spite of these discrepancies the agreement between the calculated and the measured modes may be taken as good, making all allowance for disturbance caused by the alteration of some of the constituents of the rock.

It is interesting to compare the relative amounts of the felsic [1] and mafic minerals, as shown in Tables II and III.

	Felsic.	Mafic.	$\frac{F}{M}$ ratio.	
Bekinkinite (Table II, col. VI) . .	30·7	69·3	·44	Domafic
Bekinkinite (Table III, col. I) . .	49·0	52·0	·94	Mafelsic
Bekinkinite (Table III, col. II) . .	49·9	50·7	·98	Mafelsic
Lugarite, var. 1 (Table II, col. I) .	53·9	46·1	1·17	Mafelsic
Lugarite, var. 2 (Table II, col. II) .	51·9	48·1	1·08	Mafelsic
Lugarite, var. 2 (Table II, col. III) .	55·0	45·0	1·22	Mafelsic
Lugarite, var. 3 (Table II, col. IV) .	80·6	19·4	4·15	Dofelsic

VII.—A Contribution to the Petrology of North-Western Angola.

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

(*Concluded from the July Number, p. 328.*)

Olivine ulrichite. — Megascopically this rock differs from the foregoing nepheline monchiquite in having a well-marked porphyritic structure, the phenocrysts including orthoclase and nepheline in crystals having a maximum dimension of nearly a centimetre. Under the microscope the minerals present are:—

Phenocrysts.		*Groundmass.*
Nepheline.	Titaniferous augite.	Anorthoclase.
Sanidine.	Ægirine-augite.	Amphiboles.
Anorthoclase.	Ægirine.	Pyroxenes.
Barkevikite.	Olivine and serpentine.	Calcite.
Arfvedsonite.	Analcime.	Apatite.
Augite.		Iron-ores.

Nepheline and *sanidine* call for no special description. *Anorthoclase* is similar to that in the phonolites. The anorthoclase of the groundmass, in small prisms arranged at various angles, was determined by its optical characters and specific gravity.

[1] The terms *felsic* and *mafic* have been proposed by Cross, Iddings, Pirsson, and Washington (*Journ. Geol.*, xx, p. 560, 1912) as names for two main groups of rock-forming minerals, the one including quartz, felspars, and felspathoids; the other, pyroxenes, amphiboles, micas, olivine, iron-ores, etc. Variation in the relative proportions of these two groups constitutes the important mode of variation in igneous rocks which gives rise to leucocratic, mesocratic, and melanocratic types. A quantitative expression may be given to this variation by attaching the prefixes *per-* and *do-* to the terms *felsic* and *mafic*, with a similar connotation in respect to the mode as the analogous terms persalic, dosalic, etc., have in respect to the norm of the American Quantitative Classification.

perfelsic . . .	$\frac{\text{felsic}}{\text{mafic}} > \frac{7}{1}$	leucocratic types.
dofelsic	,, $< \frac{7}{1} > \frac{5}{3}$	
mafelsic	,, $< \frac{5}{3} > \frac{3}{5}$	mesocratic types.
domafic	,, $< \frac{3}{5} > \frac{1}{7}$	melanocratic types.
permafic	,, $< \frac{1}{7}$	

Analcime is seen in roughly circular spaces, surrounded by the coloured minerals, some of which are arranged at sharp angles suggesting the trapezohedron form. This mineral is more abundant as phenocrysts than in the nepheline monchiquite, but seems to be absent from the groundmass.

The chief amphibole present is barkevikite, which differs from that of the nepheline monchiquite only in having somewhat darker colours. A little arfvedsonite is associated with it. The pyroxene series, again, is very similar to that already described (p. 324), except that the titaniferous augites are larger and more independent of the ægirine-augites. Another difference lies in the absence of long wisp-like growths, stout prisms of all sizes up to 1 mm. being the chief habit developed.

The rock differs sharply from the nepheline monchiquite in the total absence of sphene and in the presence of phenocrysts of olivine. These are about the same size as the larger titaniferous augites, averaging 1 mm. in length. Idiomorphic forms are rare, and the crystals have been altered to serpentine along numerous cracks and around the borders. Many of the crystals are surrounded by small prisms of barkevikite and ægirine-augite.

Although the rock has not been analysed, it bears so close a mineralogical resemblance to the ulrichite of Dunedin, New Zealand,[1] that the writer has no hesitation in applying to it the same name. Ulrichite seems to occupy the same position among the dyke rocks as canadite, recently defined by Quensel,[2] holds among the plutonic rocks. Canadite is a nepheline syenite, rich in mafic minerals, and containing normative lime-soda felspar, which does not necessarily appear in the mode of the rock. Ulrichite may be defined in the same way with reference to the tinguaites, and as already discussed in the case of monchiquites; it would save much confusion to retain the term ulrichite for olivine-free varieties, and describe those containing olivine as *olivine ulrichite*.

Nepheline phonolite (grey).—Megascopically the rock consists of a green-grey aphanitic groundmass in which large tabular phenocrysts of nepheline and sanidine are distributed. The former are of a yellow colour with an occasional reddish hue, and may reach a length of 1 inch. The sanidines are thin and glassy, and exhibit Carlsbad twinning; they rarely exceed ½ inch in length. On the weathered surface long ridges of nepheline stand out above the less resistant groundmass. Under the microscope, the following minerals are seen to be present:—

Phenocrysts.	*Groundmass.*
Nepheline.	Anorthoclase and nepheline.
Sanidine (with inclusions of albite and a mineral of the sodalite group).	Ægirine and ægirine-augite.
Anorthoclase.	Calcite.
Ægirine-augite.	Iron-ores.
Analcime.	Brown decomposition products.
	Isotropic base probably consisting of analcime.

Almost all the *sanidine* phenocrysts contain rhomb-shaped

[1] P. Marshall, Q.J.G.S., lxii, p. 397, 1906.
[2] P. Quensel, Bull. Geol. Inst. Upsala, xii, p. 130, 1914.

inclusions of albite, some of which show lamellar twinning. There are also inclusions of a clear and colourless mineral having a much lower refractive index than orthoclase. The inclusions are idiomorphic and present four- or six-sided sections, some of the latter being elongated in one direction. These features point to their belonging to the sodalite group, but further identification is not possible on account of the minuteness of the individuals.

The phenocrysts of *anorthoclase* differ from those of sanidine in being smaller in their dimensions, in having a slightly higher refractive index, more obscure boundaries, minute twin striations, and a mottled extinction.

Nepheline is not abundant except as large crystals, and very tiny ones which enter into the make-up of the groundmass. It is noteworthy, in view of the presence of cancrinite in the associated dyke rocks and nepheline syenite, to notice its absence both from this and the brown phonolite. A small phenocryst of *analcime* was seen in one section attached to a nepheline.

Ægirine-augite is rare as phenocrysts, but in short needles and grains in the groundmass it is abundant. Needles and flakes of ægirine are also present, the extinction being nearly straight, and the pleochroism strong in tints of yellow-brown, yellow-green, and blue-green. Amphiboles are entirely absent, though there are numerous ragged shreds and aggregates of a brown decomposition product, which may represent some variety of hornblende. Laths of nepheline and anorthoclase can be distinguished in the groundmass, and interspersed between them and the pyroxenes is a clear glassy isotropic base, which may be glass or analcime.

The rock was crushed, and the material which floated in bromoform diluted with benzine to give a liquid of specific gravity 2·28, was collected. Most of the grains were completely isotropic, and after washing and drying, their refractive index was found to lie between those of castor-oil (1·48) and xylol (1·495). These details, together with the fact that the rock contains over 2 per cent of combined water, point to the identity of the isotropic base with analcime, or with a glass of similar composition. While no signs of crystalline structures on the one hand, or of devitrification or flow-structures on the other, can be discerned, the exact nature of the base must remain in doubt, though its correspondence in all essential respects with the analcime phenocrysts of the associated ulrichite throws the balance of evidence in favour of its being *analcime*.

Nepheline phonolite (brown).[1]—In this rock the phenocrysts are smaller than those of the preceding, but nepheline in good idiomorphic crystals is much more abundant, while orthoclase is subordinate. The minerals present are as follows:—

Phenocrysts.	*Groundmass.*
Nepheline.	Anorthoclase and nepheline.
Sanidine (with inclusions of albite and calcite).	Ægirine and ægirine-augite.
Anorthoclase.	Iron-ores.
Ægirine-augite.	Isotropic base with calcite and indeterminate brown pleochroic patches.

[1] Pl. XI, Fig. 4.

Among the phenocrysts, those of *nepheline* differ from those in the grey phonolite only in size, and in having numerous inclusions of tiny laths of ægirine, arranged in rows, just within and parallel to their borders. *Anorthoclase*, as before, is present in long, narrow, vaguely outlined laths. The *sanidines* are free from inclusions of a sodalite-like mineral, but irregular patches and streaks of *calcite* and of the brownish glassy base are common.

Ægirine-augite occurs in dark-green, spongy crystals, in ragged shreds and patches, and to a less extent in small needles and tufts. The *groundmass* is yellow to brown in colour, and is frequently broken by tiny laths, often radiating from a common centre, of anorthoclase and nepheline, and by granular masses and blebs of calcite. The latter does not appear to be the result of alteration by weathering, and its presence with glass in the felspar phenocrysts suggests the view that it is an original product of the magma from which the rock was formed. It is noteworthy that cancrinite is present in the rocks described in the July number, and the calcium carbonate of that mineral may be here represented as free calcite.

The greater part of the base is isotropic, but there are a few pleochroic (yellow to brown) areas of indefinite form. They may represent a phase in the magmatic decay of hornblende under superficial conditions, for otherwise this mineral is not represented in the volcanic rocks.

Summary and General Considerations.—In the following table the mineralogical constituents of the five rocks described are summarized and their specific gravities are added:—

Mineral.	Nepheline Syenite (Foyaite).	Nepheline Monchiquite.	Olivine Ulrichite.	Nepheline Phonolite (grey).	Nepheline Phonolite (brown).
Nepheline . .	x	x	x	x	x
Cancrinite .	x	x	–	–	–
Calcite . .	–	–	x	x	x
Analcime or isotropic base	–	x	x	x	x
Anorthoclase .	–	–	x	x	x
Perthite . .	x	–	–	–	–
Orthoclase or sanidine .	x	–	x	x	x
Barkevikite .	–	x	x	represented by decomposition products?	
Arfvedsonite .	x	x	x		
Hastingsite .	x	x	–		
Augite . .	x	x	x	–	–
Titaniferous augite . .	x	x	x	–	–
Ægirine-augite .	x	x	x	x	x
Ægirine . .	x	x	x	x	x
Ilmenite and magnetite .	x	x	x	x	x
Sphene . .	x	x	–	–	–
Olivine . .	–	–	x	–	–
Biotite . .	x	–	–	–	–
Zircon . .	x	–	–	–	–
Sp.gr. . .	2·60	2·67	2·72	2·47	2·56

The whole suite of rocks is characterized by a common association of minerals. The absence of analcime from the foyaite and of cancrinite and amphiboles from the phonolites is entirely consistent with the usual behaviour of these minerals under the varying conditions which control the crystallization of magmas. Calcite is present in the phonolites and in the olivine ulrichite in precisely the same way as cancrinite occurs in the other rocks. Amphiboles, recognizable as such, are absent from the phonolites, but decomposition products which may well be their representatives, still remain. There is, therefore, strong mineralogical evidence pointing to consanguinity and differentiation from a common magma. The rocks differ chiefly in the relative proportions of the minerals present, and in the structures determined by those proportions and by the mode of crystallization. The only exceptions to this are found in the isolated occurrence of olivine in olivine ulrichite and in the absence of sphene from that rock and from the phonolites. With these exceptions the foyaite and the nepheline monchiquite clearly represent leucocratic and melanocratic phases respectively of an original magma which may be closely approximated to by the phonolites. In the absence of field evidence as to the relative abundance and order of intrusion, it is not yet possible to go further in the attempt to elucidate the origin of the various rock-types.

No basaltic rocks were collected by Colonel Andrade, but near the old fort of Duque de Bragança (lat. 9° S., long. 16° E.), which is not far from the road between Senza and Bango, M. John Monteiro discovered in 1875 [1] a series of trachytes and of porphyritic basalts, which still await description.

With the exception of a brief note by M. Pereira de Sousa in 1913, there has hitherto been no published record of nepheline-bearing rocks in South-West Africa between Namaqualand and the Kamerun. Nepheline syenites and phonolites, with associated intrusions of a barkevikite-bearing monchiquite, occur near Pomona, just to the north of the Orange River.[2] Nepheline syenite has also been found to the west of Kamerun Mountain, and in the Benue Valley between Yola and Garua in Adamaua,[3] associated in the latter locality with nepheline basalts and phonolites. The suite of nepheline rocks described in this paper falls midway between Pomona and Kamerun, and the gap has now been further bridged by Professor J. W. Gregory's discovery of a similar suite of rocks at Chiucca in the province of Benguela, where alkaline volcanics occur in association with solvsbergite and shonkinite.

[1] P. Choffat, Mém. de la Soc. Phys. et d'Hist. Nat. de Genève, xxx, No. 2, 1888.

[2] See also Kaiser, in Bibliographie Géol. du Portugal et de ses colonies, ser. II, 1913, p. 21.

[3] Passarge, *Adamaua*, 1895, p. 384.

REVIEWS.

I.—Museum of Practical Geology.

A Handbook to the Collection of Kaolin, China-clay, and China-stone in the Museum of Practical Geology, Jermyn Street, London, S.W. By J. Allen Howe, B.Sc., F.G.S., Curator. With an Appendix by Allan B. Dick. pp. viii, 271, pls. ix. London: Darling & Son, Ltd., 1914. Price 3*s.* 6*d.*

IT is a curious technological fact that our knowledge of the constitution of many materials which owing to their useful properties have acquired an extended application is decidedly limited. Bleaching powder and Portland cement might be cited as examples among inorganic materials, and india-rubber among organic substances. A large amount of investigation has been directed towards elucidating the constitution of bleaching powder, the chemical changes that occur during the setting and hardening of cement, and to the isolation of the various constituents which collectively form india-rubber, but it can hardly be said that the last word has been uttered on these problems.

The handbook now under review contains ample evidence that we do not fully comprehend either the mode of origin or the constitution of the essential raw material of what is credited with being the most ancient of the arts. Though nominally a handbook to the collection of Kaolin, China-clay, and China-stone in the Museum of Practical Geology, the volume would be far more accurately described as a valuable guide to the study of Clays, and contains information of service not only to the geologist and clay-worker but to many other classes of inquirers.

The introduction and chapters iv and v give a brief account of the nature and uses of china-clay and china-stone. The second chapter, describing the discovery, development, and method of mining the famous deposits of Cornwall and Devon, contains matter interesting not only to the general reader but also to those more directly connected with the industry. The inclusion of this chapter is particularly serviceable, since it covers the ground of *A Treatise on China Clay*, written by David Cock more than thirty years ago, which, unfortunately, is out of print and scarce. Chapter iii has given to English readers an account of the distribution of kaolins all over the world, which certainly has never been easily accessible hitherto. Chapter vi affords a very fairly complete survey of our present knowledge of some of the physical characters and chemical constitution of kaolinite and several minerals allied to it.

Chapter vii, on the origin of kaolin, will naturally appeal most strongly to the geologist, and certainly affords him an excellent and critical examination of the various theories that have been advanced to account for the existence of china-clay rock. This fascinating problem is by no means as simple as it might at first appear. The simple explanation, found in all textbooks on geology, of the process by which the felspars of solid granitic masses have been converted into friable, white kaolin, though possibly sufficient in a few cases, has long been recognized as incomplete, especially by those acquainted with the deposits of Cornwall and Devon. Two or three facts may be mentioned here, of which the ordinary theory of 'surface weathering' does not seem to afford a satisfactory explanation. For instance, the existence of extensive tracts of unaltered granitic rock in many localities at once indicates that the decomposing action of water and carbon dioxide on felspar is not universal, and it would not seem unfair to throw on the advocates of this theory of kaolinization the onus of explaining what factors have been operative in causing this selective action on the part of the decomposing agents. That kaolin would be easily and quickly removed by the ordinary agents of denudation is not a sufficient explanation, for then such granitic masses as those referred to would show signs of erosion where the kaolinized material had been removed. From a purely chemical point of view, too, the ordinary theory of weathering does not make at all clear by what mechanism two molecules of chemically combined water became an integral part of the argillaceous compound. A satisfactory explanation of this process may reasonably be demanded of any theory of kaolinization, especially in view of the fact that water can only be reintroduced into a dehydrated clay with the greatest difficulty, even if at all. At the same time it must be frankly admitted that the chemistry of the conversion of felspar into kaolin is very complex, and it is perhaps not too much to say that no theory of kaolinization at present propounded affords a complete explanation of all the reactions involved. There seems no doubt that during the decomposition of the original rock a number of secondary minerals had been formed, and consequently a number of secondary chemical reactions must have occurred, which only increase the difficulty of tracing the stages by which felspar has been converted into kaolin. The depth to which the deposits extend and the improvement in quality—in other words the more complete kaolinization—which is often found with increasing depth, are phenomena that certainly lend strong support to the theory that in such areas the action has passed from below upwards. The advocates of particular theories have perhaps been over ardent in support of their own pet theory and prone to disregard the value of others. Certainly a perusal of the evidence given in these pages, supported as it is by copious references to original papers, is enough to show that the problem cannot be said to be solved, and it was a happy inspiration which led the author of the handbook to conclude his summary of the theories with the quotation from F. W. Clarke: "Kaolin, like many other substances, may be formed by any one of several processes, in all of which water, hot or cold, and carbonic acid take part. No one interpretation can fit all its occurrences."

The details of composition and various physical properties of china-clays from many localities, in chapter viii, together with the statistics and list of china-clay works in England, are most useful additions, brought together in compact form, so far as we can remember, for the first time.

No remarks on this handbook would be complete without reference to Appendix 1, from the pen of Mr. Allan B. Dick, which describes a novel way of examining mineral fragments under the microscope, in especially selected media of requisite refractive indices, with dark ground illumination. Only those who have had the advantage of seeing the method in operation can fully appreciate its beauty and the ease with which kaolinite crystals can be detected, and it is to be hoped that the method will find considerable application in that very difficult region of investigation, the microscopic examination of clays.

In 1893 the handbook to the Collection of British Pottery and Porcelain at Jermyn Street was issued and formed the first of the series of handbooks that replaced mere catalogues. The valuable notes on British Clays compiled by Mr. George Maw were included in that volume, and a worthy successor to it has been found in the handbook under review, which forms the second publication on clays issued from the Museum of Practical Geology. Information with regard to clays is scattered and often inaccessible, and it is to be regretted that greater advantage is not taken of such publications as those just mentioned. Textbooks on geology and chemistry give almost nothing, and anyone wishing to get an insight into the properties of clays could hardly be better advised than to read these handbooks. The study of clays has not received the attention it deserves, and the fact is often overlooked that the output of clays, together with the closely allied material, shale, in this country is only exceeded by two other mineral products, coal and iron-ores. Though a large portion may be of relatively low value, still clay is the essential constituent of products which range from an exquisite work of art to a common building brick, and without refractory clays hardly a single manufacture could exist.

In conclusion, the author is to be congratulated on having attained two dissimilar objects in one volume with marked success; the general visitor to the Museum is provided with an interesting handbook, and the specialist with a valuable scientific textbook. Kaolin might perhaps be described as the fundamental or parent clay, but owing to the remarkably complete series of geological formations represented in this country, we have many deposits of great economic value which supply raw material for all branches of ceramic manufacture, such as ball clays, stoneware clays, and fire-clays. Consequently it would seem that the authorities at the Museum of Practical Geology would be fulfilling the mandate received in 1835 "to form collections illustrative of the mineral wealth of the country and of the applications of its various mineral substances to the useful purposes of life", if the present handbook were followed up by others, dealing with the special and more important classes of clays such as those just mentioned, and gigantic though the task might be it is not too much to say that its execution could not be in better hands than those of the present Curator.

W. C. H.

II.—Geological Survey of New Zealand.

Revision of the Tertiary Mollusca of New Zealand, based on Type-material. Part I. By Henry Suter. Palæontological Bulletin, No. 2, New Zealand Geological Survey (P. C. Morgan, Director). 4to; pp. 64, pls. i–xvii, with a transmittal letter by P. G. Morgan and a preface by J. Allan Thomson. Wellington, 1914.

The authorities of the New Zealand Geological Survey are to be congratulated on having secured the services of so well known a conchologist as Mr. Henry Suter, member of the Malacological Society of London, to undertake the revision of their Tertiary Mollusca from that country. His long experience as a student and a writer of the living shells of New Zealand has specially fitted him to accomplish so important and necessary a task.

As a first fasciculus in this direction the present memoir deals entirely with the type-material which formed the basis of the late Captain F. W. Hutton's *Catalogue of the Tertiary Mollusca and Echinodermata of New Zealand in the Collection of the Colonial Museum*, published in 1873, a revision of which has been long required from the fact that it included a number of brief diagnoses of new species without the support of illustrations, although certain "lithographed plates" were promised to be "issued shortly" in a preface written to the work by the late Sir James Hector, which, however, were never forthcoming. Some of these new species were subsequently figured by Hutton in his monograph on *The Pliocene Mollusca of New Zealand*, which formed part of "The Macleay Memorial Volume", issued under the auspices of the Linnean Society of New South Wales in 1893. Since that date palæontologists have been mainly indebted for any further knowledge of the subject to the writings of the late Mr. G. F. Harris, whose excellent treatise on *The Australasian Tertiary Mollusca in the British Museum*, published during 1897, included several forms from New Zealand. In addition to such memoirs it must not be forgotten that many species of New Zealand Tertiary Mollusca had been previously described and figured by the late Professor von Zittel in his *Fossile Mollusken und Echinodermen aus Neu-Seeland*, forming vol. i of the "Novara Expedition" report of 1864. In this connexion Zittel's researches were of peculiar geological interest because, from a study of the palæontological works of G. B. Sowerby and Alcide d'Orbigny on South America, he was able to trace a resemblance between the Tertiary faunas of New Zealand and those of Chili and Patagonia, the existence of such a relationship having been strongly supported since by Dr. Ortmann and the later specialists who met recently in Australia to discuss this and sundry matters appertaining to the age of the Lower Tertiary rocks of Australasia.

A considerable reduction in the number of molluscan species has been the outcome of this revision, Mr. Suter having recognized 101 species and varieties, consisting of 44 Gastropoda, 3 Scaphopoda, and 54 Pelecypoda, as against Hutton's estimate of 275 species, made up of 127 Gastropoda, 9 Scaphopoda, and 139 Pelecypoda—a result which should be welcome to all students of the Tertiary shells of New Zealand as tending to simplify a somewhat complicated subject. The author contributes carefully prepared diagnoses of the species, but has failed to include the original descriptions as given in the Hutton Catalogue: had that been done we should have been better able to institute comparisons between the old and the new determinations, a plan which, we think, would have rendered the *Revision* of greater historical and scientific importance.

The generic nomenclature adopted in the work appears to be generally on an up-to-date basis, as an instance of which we may observe that *Turris* of Bolten is used to the exclusion of Lamarck's *Pleurotoma*, the former finding a place in Gray's Catalogue of 1847, although since that time the name has been more commonly adopted by American rather than by British conchologists. Attention may here be directed to one of the Pelecypod determinations—*Pecten* (*Camptonectes*) *huttoni*. This is a true *Pseudamussium*, as long since acknowledged both by G. F. Harris and Professor Park, and therefore quite distinct from Meek's *Camptonectes*, which is a characteristic genus of the Mesozoic period, possessing very unequal auricles as in *Chlamys*, and furnished with divergent, bifurcating, and punctated striations which are more or less obsolete over the umbonal half of the valve.

It is to be regretted that the geological information is of so meagre a description. We could have wished that a scheme of the fossiliferous marine Tertiaries of New Zealand had been inserted for the benefit of the student, together with a good topographical map. In the meantime we may here generally state that the Tertiary rocks of New Zealand are recognized as being divisible into two great groups —the Oamaru and the Wanganui, the former, comprising the Pareora, Waihao, and some other Series, being of Miocene age, whereas the Wanganui rocks belong to the Pliocene system, and embrace the Petane, Waitotara, and Awatere Series. From the horizons that accompany the specific descriptions we gather that the author regards the older Tertiary beds of New Zealand as of Miocene age, and not Eocene as was formerly supposed, this being in agreement with the strictest modern views that there are no true marine Eocene deposits throughout Australasia. Finally, this work is excellently printed and illustrated with good photographic plates, while the genera and species are most completely indexed. We shall look forward with much pleasure to a later fasciculus which is promised, and which is to contain a revision of the specific types of New Zealand Tertiary Mollusca established since 1873.

R. B. N.

III.—Tertiary Echinoids from the San Pablo Group of Middle California. By William S. W. Kew. Univ. California Publ. Geol., vol. viii, No. 20, March 2, 1915. pp. 365–76, pls. xxxix–xl.

Of the variability of the Clypeastroids there is no end, and of the torrent of species thereof described there is little sign of diminution. From the number of intrapetaloid tubercles that have escaped denudation, to the fourth place of decimals of the proportionate length of a petal, each and every detail seems to suffice for specific separation. Surely one of the first and most essential parts of the curriculum of a larval systematic palæontologist should induce him to collect, measure, and specifically distinguish every several leaf from a well-grown tree. After such preliminary training, the ardour of the image might be appreciably subdued.

The present paper has two distinct merits above many of its kind. Only two new species and two smaller divisions are named; and a concise index to their relative stratigraphical occurrence is supplied. But the characters on which the specific and varietal divisions are made do not appear to be of great importance, and no attempt is made to demonstrate their meaning, if any. The latter criticism may well be answered by the explanation that sufficient material is not yet available; but such an excuse would tend to suggest that the whole matter might be left alone until such material has been collected.

In two long-ranged forms like *Scutella gabbi* and *Astrodapsis tumidus* there will be, in all probability, a progressive series of modifications into well-marked directions. Until the trend of the variation can be postulated, would it not be safer to defer the introduction of new names which have no certain biological significance, and which may lead even stratigraphers astray?

H. L. H.

IV.—The American Journal of Science.

VOL. XXXIX of the *American Journal of Science*, 1915, contains three important papers emanating from the Carnegie Institute and dealing with the crystallization, under laboratory conditions, of certain silicate mixtures. The first, by Mr. C. A. Rankin, describes the ternary system lime-alumina-silica. Although the compounds of these substances show no solid solutions, nevertheless the relations are very complex, owing to the large number of minerals that are possible: these are quartz, tridymite, cristobalite, corundum, wollastonite, sillimanite, and anorthite, together with several calcium silicates not known to occur in nature. The equilibrium diagram contains no less than fourteen separate fields. The chief application of the results is to the study of Portland cement. A subsidiary point of geological interest is the observation that eutectics of silicates have in general no structure differing from that of other mixtures, except that they are very fine in grain. This is of some significance in connexion with certain igneous rocks. In another paper Mr. Olaf Andersen describes the system anorthite-forsterite-silica. In some mixtures spinel is found to be a primary phase, while in others the unstable substance clino-enstatite is formed. This is not a true ternary system and can only be expressed in terms of the four-component system lime-magnesia-alumina-silica. It is shown that under certain conditions forsterite undergoes resorption without any change of physical environment, a fact which has an important bearing on the magmatic resorption of olivine in certain peridotites and anorthite rocks. When the olivine becomes surrounded by a shell of its decomposition products, quartz and olivine may be found in the same rock. Mr. N. L. Bowen discusses crystallization-differentiation in silicate liquids and shows experimentally that crystals sink with considerable rapidity in artificial melts. Hence this process may be of importance in the differentiation of igneous magmas.—R. H. R.

V.—The Petroleum Occurrences of Assam and Bengal. By E. H. Pascoe, M.A., D.Sc. Mem. Geol. Surv. India, vol. xl, pt. ii.

The present volume forms a fitting sequel to the author's recent work on the Oil-fields of Burma, which has made Further Indian oil-fields better understood than many of those in Europe and America.

The Coal-measures series in which the oil occurs is almost certainly the homotaxial equivalent of the Pegu Beds of Burma. They are underlain by the Nummulitic Series, while the overlying Tipam Sandstones are very similar to the Irrawadi Beds. It would appear that whereas the Burma oil-fields occur in the Hinterland behind the region of maximum mountain-building movement, those of Assam form a belt in the Forland a little to the west of the great boundary thrust, and have suffered more intense folding. The author infers overfolding in each of the main oil-fields, and although the poor exposures and dense forest render the matter difficult of proof, the balance of evidence appears to favour this view. The folding is probably accompanied by thrusting, and the structures produced are very similar to those of some of the Carpathian oil-fields.

Another point of interest is the supposed interference of the Himalayan and Burmese movements in the north-eastern portion of the area. The close association of oil and coal, and the sparsity of animal remains, certainly support the views of the geologists of Burma, that in these beds of Further India the natural hydrocarbons are mainly of vegetable origin.

VI.—Brief Notices.

1. Earthquakes in Burma.—In the month of May, 1912, Burma was visited by severe earthquakes, which culminated in a great shock on the morning of May 23. This was sensible over an area of 375,000 square miles, and caused much damage in Mandalay, Maymyo, and other places, though attended by little or no loss of life, owing to the character of the buildings. This shock is described in detail by Mr. J. Coggin Brown (Mem. Geol. Surv. India, vol. xlii, pt. i). In the central part of the area the shock reached the intensity of ix on the Rossi-Forel scale, although this isoseist could not be exactly delimited; the other isoseists had an elliptical form, with their long axes running north and south. The position of this long axis coincided very nearly with the great Kyaukkyan fault, described by Mr. La Touche as one of the most notable features of Burmese geology; the railway was bent where it crosses this fault, but unaffected where it crosses the other faults of the plateau. No actual surface displacement was anywhere observed.

2. Ferberite in Colorado.—The rare mineral ferberite occurs in workable quantities in Boulder County, Colorado. An exhaustive account is given by Messrs. Hess & Schaller (Bulletin 583, United States Geological Survey, 1914). The end members of the wolframite series are ferberite, $FeWO_4$, and hübnerite, $MnWO_4$; wolframite is an isomorphous mixture of these two compounds. The ferberite of Boulder County occurs in beautifully developed, though small crystals, some of a wedge shape, others of almost cubic habit; also massive and in blades. They are black, almost metallic, and opaque in thin sections. All known analyses of the wolframite group are tabulated and criticized, and an appendix contains an elaborate crystallographic discussion.

3. Bulletin 577 of the United States Geological Survey contains a very full description of the geology of the phosphate deposits north-east of Georgetown, Idaho, by Messrs. R. W. Richards and G. R. Mansfield. The phosphate-bearing rock is an oolitic sediment associated with limestones, and probably of Permian age: near the out-crops it seems to have undergone secondary enrichment by weathering. Average samples generally show about 32 per cent of phosphoric acid, and the amount of rock available is estimated at more than 2,500,000,000 tons. The geological structure of the district is very complicated, including an overthrust which has carried Carboniferous rocks for a distance of some 12 miles over Cretaceous and Eocene strata: consequently in places the phosphate beds are buried too deeply to be worked. No satisfactory explanation of the origin of the phosphatization is forthcoming.

4. In the Bulletin of the Geological Society of America, vol. xxv, pp. 277–320, 1914, Mr. Charles Schuchert describes his work on the Medina and Cataract formations of New York and Ontario. It is shown that the Cataract formation of Ontario, formerly ascribed to the Clinton, is really equivalent to the typical Medina of New York, while the Brassfield Beds of Ohio are of about the same age. The variations are due to deposition in marine areas with only limited connexion, encroaching from different directions. The Medina is essentially a sandstone facies, while the others are calcareous. The second part of the paper contains an historical review of research on these rocks, together with full descriptions of sections and lists of fossils.—R. H. R.

5. North American Geology.—The valuable Bibliography of North American Geology has appeared for 1913. It is compiled and indexed by J. M. Nickles and is a model of what such publications should be. It includes all papers on the North American Continent and adjoining islands, as well as Panama and the Hawaiian Islands. There are 1,357 items.

6. Potash in the Texas Permian.—The impossibility of securing shipment from Germany of potash has led the Texan Bureau of Economic Geology to investigate the sources of supply in that State. The results are highly satisfactory, and Mr. J. A. Udden has issued a detailed report in the Bull. Univ. Texas, 1915, No. 17.

7. Rhodesia Museum, Department of Geology.—Owing to the departure of Mr. Macgregor for England in February, 1915, a detailed account of the progress of the Geological Department during the past

year cannot be included in the report for 1914. A considerable amount of work has been done within the year, in spite of the serious hindrance to development due to the lack of cases and room. In addition to arranging and classifying the present collections and additions received during the year, much of Mr. Macgregor's time has been absorbed in making determinations for the public. Fifty-seven such determinations were carried out, including twenty-three rock-slides, besides a number of determinations at sight. Two collecting trips were made by Mr. Macgregor—one to Shiloh, for the purpose of searching for fossils of the Forest Sandstone formation, the other to the Bembesi Diamond Field and Somabula and Victoria districts. Although no success attended the first of these journeys, the second resulted in the acquisition of many valuable mineral and rock specimens.

8. Anticosti Island.—This island consists of a part of a cuesta on an ancient coastal plain which probably began to develop in the Devonian and existed until the time of the post-glacial submergence. It will be called the Anticosti cuesta. About 20 miles to the north the Mingan Islands fringe the Quebec shore and consist of the remnants of a parallel cuesta. This will be named the Mingan cuesta. Between the two cuestas lay an inner lowland which near the west end of Anticosti was crossed by a north–south divide from which streams drained east and west, the former being the larger. North of the Mingan cuesta is another lowland. The latter will be called the Laurentide lowland and the former the Channel lowland. In these words Mr. Twenhofel (Canada, Dept. Mines, Mus. Bull., No. 3, 1914) describes the structure of Anticosti Island, and then proceeds to give faunal summaries of the various formations for the Ordovician and Silurian systems. He describes a few new species of fossils, and promises an exhaustive memoir on the geology and palæontology later.

9. Leeds.—The activity of the Leeds Geological Association may be gathered from the last number of the Transactions (part xvii, 1911–13, November, 1914). Miss S. E. Chapman writes on "Some Petrological Characteristics of Underclays"; Mr. C. Thompson, "Ammonites of the Lias"; P. F. Kendall, "Evidences of Climatic Changes in Geological Times"; Burnet & Everett, "Sections in a Quarry at Robin Hood, near Leeds", in the Middle Coal-measures. Many excellent photographs and quite a good list of plants accompany this last paper.

10. *Beatricea.*—This very old friend and puzzle to the palæontologist has turned up in the Middle Ordovician of South Pennsylvania. It was first noticed there by Ulrich in 1908, and P. E. Raymond has seen the specimens and described them in detail in Canada, Dept. Mines, Mus. Bull., No. 5, 1914. Raymond gives very fine photographic sections, and though he inclines to the Stromatoporoid view of their relationships he cautiously refers to them as "early Palæozoic organisms". Moreover, he does not consider that Ulrich's specimens are true *Beatricea*, and proposes for them the new generic and specific name of *Cryptophragmus antiquatus*. Mr. Raymond has done good service in presenting us with such excellent figures for study.

11. Jurassic Brachiopoda.—In June, 1914, Mr. S. S. Buckman, who has been working for some years on a large series of Brachiopoda from Burma, issued a single sheet (through Messrs. Wesley & Son) of new generic names, to which he attached the name of the genotypes. This he circulated freely with No. xiv of his "Yorkshire Type Ammonites", June, 1914, and now (May, 1915) the same with additional matter appears in his "Brachiopoda of the Namyall Beds of Burma" (Records Geol. Surv. India, xiv, pt. i), which is a preliminary notice of a monograph now in course of printing in the *Palæontologica Indica.*

While opinions may differ as to the advantages of these preliminary notices, it is only fair to point out that, with so many workers in the same field, 'cutting out' is as often due to the dilatoriness of the original author as to the want of honour in a rival. No one has the right to hold up ideas that have been ventilated in conversation, to the hindrance of scientific progress.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

June 23, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "On a New Eurypterid from the Belgian Coal-measures." By Professor Xavier Stainier. (Communicated by Dr. A. Smith Woodward, F.R.S., Pres.G.S.)

In this paper the author records the discovery of a specimen of a new *Eurypterus* in the cores of a trial boring for coal in Belgium. He describes the fossil, which is in a very satisfactory state of preservation. To allow of comparisons, a short description of the eleven Carboniferous species known up to the present is appended. The nearest form to the Belgian fossil seems to be a Pennsylvanian *Eurypterus*, which nevertheless is not identical with the former. The author then discusses the geological range and the evolution in time of the twelve Carboniferous Eurypterids. The paper ends with a short literature on the subject.

2. "On a Fossiliferous Limestone from the North Sea." By Richard Bullen Newton, F.G.S.

The material on which this paper is based was trawled from the floor of the North Sea, some 100 miles N.E. ½ N. of Buchan Ness, and was forwarded to the British Museum (Natural History) by Mr. R. D. Thomson, of Aberdeen. It presents no appearance of glaciation, so that its occurrence in situ seems to be highly probable. There is no record of a similar limestone from either England or Scotland. It is of highly siliceous character and full of marine shells, of which the Pelecypoda are the more prominent; there are, also, occasional fragments of wood in contact with the limestone which, from a preliminary examination, appear to show coniferous characters. Some twenty-three species of Mollusca have been determined, all of which exhibit a southern facies, including ten

Gastropods and thirteen Pelecypods: the latter embrace a new Dosiniform shell belonging to the genus *Sinodia*, the relationships of which are entirely confined to the Indian Ocean regions of Southern Asia. Eighteen of the species, or about 80 per cent, trace their origin from the Vindobonian stage of the Miocene; ten, or about 40 per cent, may be regarded as extinct; whereas twelve, or 50 per cent, still exist in recent seas. The majority of the species are fairly evenly distributed in both the Coralline and the Red Crag formations of East Anglia, although, on account of so large a number being extinct, and bearing in mind their southern facies, it is thought that the rock must be of older age than Red Crag. Additional support is given to this view because such shells as *Arcoperna sericea*, *Tellina benedeni*, and *Panopæa menardi* are not known of later age in this country than the Coralline Crag. The occurrence also of the extinct Gastropods *Streptochetus sexcostatus* and *Ficus* [*Pyrula*] *simplex*, which are particularly characteristic of the Upper Miocene or Messinian deposits of Northern Germany, constitutes further evidence in favour of a greater antiquity for this limestone than that of the Red Crag: it is therefore considered to be of Coralline Crag age.

3. "The Origin of the Tin-ore Deposits of the Kinta District, Perak (Federated Malay States)." By William Richard Jones, B.Sc., F.G.S.

Certain tin-ore-bearing clays and boulder-clays occurring in the Kinta District have been described by Mr. J. B. Scrivenor, Government Geologist F.M.S., as being of glacial origin, and the tin-ore which they contain as having been derived from "some mass of tin-bearing granite and rocks altered by it, distinct from and older than the Mesozoic Granite" (that is, than the granite now in situ in the Kinta District). These clays and boulder-clays are stated to have furnished a more valuable horizon on climatic evidence than can be afforded by limited collections of fossils in rocks far removed from Europe, and have been correlated with the Talchirs of India and mapped as Older Gondwana rocks.

It would be difficult to over-estimate the importance of the origin of these clays in a country where, on the one hand, they yield a very important part of the world's output of tin-ore, and where, on the other, they have been used as the horizon on which to base the geological age of rocks which cover about a third of the surface of the Malay Peninsula. If of glacial origin, a vast tin-field remains to be discovered.

The object of this paper is to show that all the tin-ore found in these clays is derived from rocks now in situ in the Kinta District; that it is not necessary to bring in glacial action to explain any of the features which led to the adoption of the theory of their glacial origin; to point out that these deposits cannot be correlated with the Talchirs of India; and to show that a simple interpretation may be given to the geology of the Kinta District.

The sources of the tin-ore here are: (1) the stanniferous granite of the Main Range and of the Kledang Range; (2) other granite outcrops known to carry cassiterite; (3) the granitic intrusions in the phyllites and schists, notably near the granite junction; (4) the granitic intrusions traversing the limestone and forming an important source of ore.

The angularity of the boulders and of the tin-ore in some of these clays is due (1) to weathering in situ of the phyllites and schists, which then sink on the dissolving limestone underneath; (2) to soil creep effecting the same result; (3) to the breaking-up of the much weathered cassiterite-bearing boulders and pebbles in the alluvium.

Over 90 per cent of the ore worked in the whole of the Kinta District is obtained from mines situated at less than a mile from granite or from granitic intrusions.

Mineralogical Society.

June 15, 1915.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

G. M. Davies: Detrital Andalusite in Cretaceous and Eocene Sands. Detrital andalusite is not confined to Pliocene and later deposits as was formerly supposed, but is a frequent constituent throughout the Cretaceous and Eocene beds of the South-East of England. In the Lower Cretaceous beds it is still perfectly fresh, and shows no signs of instability under the influence of meteoric water.—J. F. N. Green: The Garnets and Streaky Rocks of the English Lake District. Certain peculiar rocks occurring in the Lake District are characterized by almandine garnets and parallel streaks of secondary minerals. The capricious distribution of the garnets in diverse rock-types was considered to exclude originality, and thermal or dynamic alterations were shown to be inadequate. Circulating solutions under pressure during the solfataric stage of the Borrowdale episode were suggested as the agent, and illustrations were given of the replacement of felspar by garnet in Lake District rocks. The same origin was assigned to the streaky infiltrations which frequently contain pyrites or garnet.—Dr. S. Kôzu: On the errors in the angle of the optic axes resulting from those of the principal refractive indices determined by total reflection. The indices so found are correct within 0·0002 for sodium light. Assuming the error to be only half this, the extreme values of the angle are for anorthite 76° 8·6′ and 79° 21·8′, for albite 76° 14·1′ and 80° 46·9′, and adularia 56° 16·9′ and 65° 56·9′.—Dr. S. Kôzu: The influence of Temperature on the Optic Axial Angle of Sanidine from the Eifel. Pockels has shown that in those rhombic crystals in which the axial angle varies considerably in the neighbourhood of zero the relations between the angle and the temperature is represented by a parabola. Sanidine from the Eifel very nearly approaches the conditions of a rhombic crystal. The values of 2E were determined for seven different wave-lengths. The plotted curves were found to accord with Pockels' statement; further, the complex curves for the various wave-lengths were identical.—Dr. G. T. Prior: The Meteoric Stones of Warbreccan, Queensland. Three stones, weighing respectively about 69, 64, and 1 lb., were known to the natives of Central Queensland before 1904, and their fall was probably seen. They were acquired by the British Museum in 1905. They are white-veined chrondites, and in chemical and mineral composition are similar to other members of the group.—A. F. Hallimond: On Autunite. It is concluded that the Cornish material is essentially different from the Autun mineral, and the name bassetite is proposed for the former, the fundamental characters of which are: oblique, $\beta = 89° \ 17'$, $a:b:c = 0{\cdot}3473:1:0{\cdot}3456$; forms 010, 110, 120, 011, 111, 121, $\bar{1}21$, $\bar{1}41$, $\bar{1}01$; twinning by parallel growth of *a* and *c* axes, perfect cleavage parallel to 010, also 100, 001; yellow, transparent; biaxial, 2E = 110°; pleochroic, pale to deep yellow; soluble in acids.

CORRESPONDENCE.

THE UNDERGROUND FLOW OF THE YORKSHIRE DEE IN DENTDALE.

Sir,—On walking from Hawes Junction to Sedbergh on June 23 this year, after a prolonged period of drought, I found the bed of the Dee quite dry for many hundreds of yards. The river flows over the Great Scar Limestone, and its bed forms an interesting study. Over long stretches the bare limestone was exposed, worn to a slippery smoothness and devoid of any surface pebbles or boulders, except in the numerous cylindrical pot-holes drilled by them, some of which were as much as 10 feet in diameter. Miniature cañons have been cut through the limestone, and, as Dr. Strahan[1] remarks, "the gradient of the river-bed frequently agrees with the inclination of the strata, and in such cases the water slides for many yards over the smooth surface of the same bedding plane." At intervals waterfalls occur and the river plunges from a stratigraphically higher to a lower limestone bed. This applies more particularly to the river course between the mouth of Cowgill Beck and the seventh milestone from Sedbergh. On the other hand, long stretches occur where the solid rock of the river-bed is completely hidden under a chaos of boulders or shingle. At several points pools of water occurred owing to inflow of tributary streams or springs. These pools were in some cases without visible outlet. Where boulders filled the stream bed immediately below the pool it is, of course, possible that the overflow of the pool took place over the solid rock but beneath the boulders. In other cases the only outlet for the pools must be subterranean. At one place higher up stream than the seventh milestone an inflow of several gallons per minute joined the Dee on its left bank, gushing out from a subterranean channel.[2] Whether this water was the same as that which disappeared higher up stream or not would be difficult to ascertain without chemical tests. It seems, however, clear that some of the water of the Dee follows a subterranean course, though it does not necessarily follow that it rejoins the river lower down. The underground course of the Dale Beck near Ingleborough is well known, but, so far as I know, that of the Dee has not been previously mentioned.

B. Hobson.

[1] *Geology of Country around Ingleborough* (Mem. Geol. Surv.), 1890, p. 42.
[2] I have since seen an underground inflow on the right bank above Lea Yeat.

MISCELLANEOUS.

Geologists' Association Excursion to the London Area.—Subject to possible interruption the Council has wisely arranged that the usual Long Excursion shall be held in the London area between August 25 and September 5. This has for long been suggested as affording an inexpensive and agreeable excursion for provincial members. The proceedings may commence with an evening meeting, at which a general sketch of the geology of the London district will be given, with special references to the places to be visited. Excursions, arranged for eight or ten days, will comprise field-work in the following formations: Lower Greensand (Hythe Beds and Folkestone Beds), Gault, Chalk, Thanet Sand, Woolwich and Reading Beds, Blackheath and Oldhaven Beds, London Clay and Bagshot Beds, Pleistocene deposits (Glacial Drift and River Drift), and gravels of various ages. As opportunities arise attention will be directed to the casual connexions between the geology and geography of the various localities. It is hoped that the series of excursions will form a fairly complete demonstration of the field geology and geography of the London district. Those localities marked with an asterisk will have first consideration. **Charlton*, Chalk and Lower London Tertiaries; **Crayford and Dartford Heath*, River Drift, gravels, and brick-earths, Palæolithic sites; **Dorking*, the Chalk Escarpment and the Gorge of the Mole; *Edmonton*, Lea Valley gravels, Late Arctic deposits; **Erith*, Lower London Tertiaries for comparison with Charlton; **Godstone*, Upper Greensand, hearthstone excavations, Lower Greensand, Folkestone Beds; *Grays*, Chalk, whitening and cement works, river gravels, and brick-earths; *Guildford*, Lower Cretaceous rocks, Chalk, geographical features; **Harefield*, solution phenomena illustrated by 'pipes' in the Chalk; **Herne Bay*, continuous section of Lower London Tertiaries (Thanet, Woolwich, and Oldhaven Beds) and London Clay for comparison with the sections in the London area; **Hertford and Hertingfordbury*, Glacial Drift; **Leatherhead*, the Chalk Escarpment, Vale of Holmesdale, and the Valley of the Mole; **North Downs*, Guildford, Leatherhead, Worm's Heath, and Tandridge Hill, at the two latter places outliers of Blackheath Beds, 'pipes,' and other solution phenomena; *Otford*, chalky rainwash, Gault, and the Gorge of the Darent; **Ponders End*, gravels in the Lea Valley; **Potters Bar*, swallow-holes; *Reigate*, Lower Greensand and Chalk; **Reading and Wokingham*, Reading Beds and London Clay; *St. George's Hill*, Bagshot Beds; *St. Albans*, Boulder-clay and Glacial Gravels; **Well Hill*, outliers of Woolwich and Blackheath Beds, dry valley gravel and hill gravel, swallow-holes. All members, but particularly those living in the provinces, who contemplate joining these excursions, are requested to send their names to the Secretary immediately.

Geological Survey of the Union of South Africa.—Mr. H. Kynaston, B.A., F.G.S., Director of the Geological Survey of the Union of South Africa, Pretoria, writes, under date May 10, 1915, stating there will be no Annual Report of this Survey issued for the year 1914.

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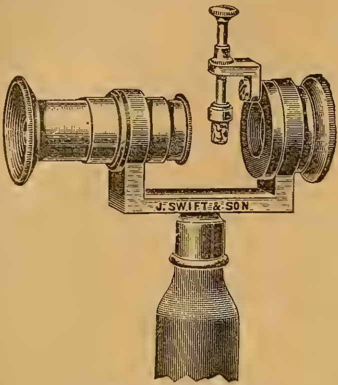

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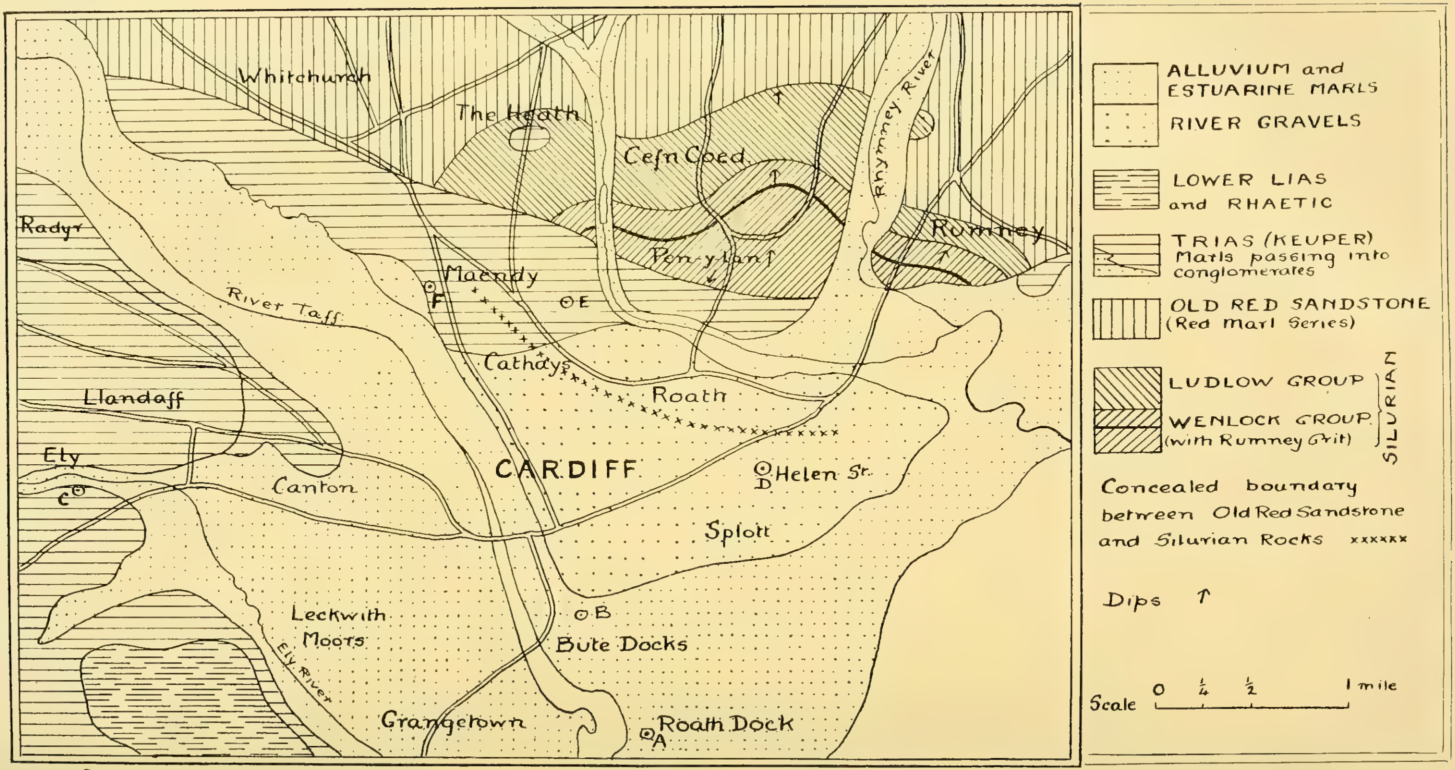

F. J. North, del.

GEOLOGICAL MAP OF THE COUNTRY AROUND CARDIFF.

(Based upon the 1-inch Map of the Geological Survey.)

THE
GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. IX.—SEPTEMBER, 1915.

ORIGINAL ARTICLES.

I.—Note on the Silurian Inlier near Cardiff.

By F. J. North, B.Sc., F.G.S., Assistant Keeper, Geological Department, National Museum of Wales.

(PLATE XIII.)

To the north and north-east of Cardiff there is a small inlier of Silurian rocks (described in detail by Professor Sollas in 1879 [1]) covering an area of rather more than two square miles. There are representatives of both the Ludlow and the Wenlock Series, and the general dip of the beds is towards the north, in which direction Ludlow mudstones pass with apparent conformity beneath the Old Red Sandstone.

That there was a considerable underground extension of strata older than the Old Red Sandstone was inferred from the fact that grey mudstones containing fossils ("brachiopods and encrinites"), and regarded as of Silurian age, had been recorded immediately beneath the Trias in deep borings in the vicinity, viz. Crown Fuel Works, Roath Dock [2]; Crawshay Street [3]; and the Ely Paper Mills [4]; but there was no definite evidence as to the structure and extent of the concealed rocks. (The sites of these borings are indicated on the accompanying Map, Plate XIII, by A, B, and C respectively.)

The dip of the Wenlock Beds in the southernmost exposures at Pen-y-lan is toward the south,[5] but this does not necessarily imply that a southerly dip would prevail, since minor folds have been noticed further north. In the Survey Memoir [6] we read: ". . . it by no means follows that the main axis of the Silurian inlier has been passed; [*at Pen-y-lan*] rocks older than any exposed at the surface may crop out under the New Red Marls at Roath."

Important evidence bearing upon this question has recently been afforded by a deep boring for water, full details of which will be published later. The boring, which was discontinued in December, 1914, after having reached a depth of 627 feet without encountering water, was made on the site of the new premises of Messrs. S. A. Brain & Co., who generously placed the cores at the disposal of the National Museum of Wales.

[1] J. W. Sollas, Q.J.G.S., vol. xxxv, pp. 475–507, 1879.
[2] *The Country around Cardiff* (Mem. Geol. Surv.), 1912, p. 99.
[3] Ibid., p. 100.
[4] Ibid., p. 99.
[5] J. W. Sollas, Q.J.G.S., vol. xxxv, p. 477, 1879.
[6] *The Country around Cardiff* (Mem. Geol. Surv.), 1912, p. 5.

SECTION OF THE BOREHOLE.

Site of boring, the southern end of Helen Street,[1] *Roath; 6 in. ordnance map, Glam. 43, S.E. Height of surface above O.D. 38 feet.*

	Thickness.		Depth from surface.	
	ft.	in.	ft.	in.
Superficial deposits.				
Soil and terrace gravels	23	0	23	0
Trias.				
Red and green Keuper marls with gypsum .	265	3	288	3
Conglomeratic series	53	9	342	0
Old Red Sandstone.				
Purple micaceous sandstone, mottled marls with cornstones ; grit band at the base .	132	0	474	0
Silurian (Ludlow).				
Red and grey fossiliferous mudstones, with sandstones and very thin calcareous bands.	152	7	626	7

The lower part of the Old Red Sandstone Series includes red micaceous mudstones in which *Lingula* and crustacean tracks occur. Beneath the mudstones there are about 6 feet of a hard grit containing fragments of the underlying rock. Mr. T. C. Cantrill, who has kindly examined some of the specimens, compares the crustacean tracks to those described by G. E. Roberts from the lower part of the Old Red Sandstone at Bouldon Quarry, near Ludlow.[2]

The Silurian rocks yielded a rich fauna, including many Mollusca, Brachiopoda, and Trilobita. The beds are regarded as of Ludlow age, for although many of the forms present are such as occur in both Wenlock and Ludlow beds of other localities, certain species, e.g., *Homalonotus knightii*, König, *Murchisonia lloydi*, J. de C. Sowerby, *Stropheodonta filosa* (J. de C. Sowerby), *Chonetes striatella* (Dalman), and *Cyclonema turbinatum*, Sollas, are especially characteristic of the local Ludlow beds.

The general direction of the concealed boundary between the Silurian and the Old Red Sandstone can now be inferred from the following evidence:—

1. Trias was found to rest upon Silurian strata in a boring by the side of the Rhymney Railway, about 500 yards south of the main Silurian outcrop,[3] at a spot indicated by E on the accompanying map.

2. In the Cardiff Brick Company's pit at Maendy (F on the map), Trias rests upon Old Red Sandstone.[4]

3. In the Helen Street boring, now described, Trias rests upon Old Red Sandstone.

The junction therefore occurs north of a line from Maendy to Helen Street, and south of the spot E; its approximate position is indicated on the map.

If the Trias were removed, the Cardiff Silurian inlier would appear as an oval mass, about three miles from east to west and about two miles from north to south. Structurally it is an anticlinal fold, trending in an east to west direction, i.e. in the direction of the

[1] Indicated by D on the accompanying Map (Plate XIII).
[2] G. E. Roberts, Q.J.G.S., vol. xix, pp. 233–5, 1863.
[3] *The Country around Cardiff* (Mem. Geol. Surv.), 1912, p. 105.
[4] Ibid., p. 17.

greater Cardiff–Cowbridge anticline. The occurrence of Silurian rocks beneath the surface at the localities already cited does not indicate one continuous Silurian mass, immediately beneath the Trias, extending from Pen-y-lan on the north to the Bristol Channel on the south, and from Rumney on the east at least as far as Ely on the west. There are probably several small oval areas which owe their existence to pre-Triassic folding and denudation. In conclusion, the writer would express his thanks to Professor T. Franklin Sibly for his advice while the work was in progress.

II.—The Genera of Recent and Tertiary Rhynchonellids.

By J. Allan Thomson, M.A., D.Sc., F.G.S.

Owing to the marked persistence of general external form and internal characters in the Rhynchonellidæ, it is necessary in this family to seize on slighter differences for the foundation of genera than is elsewhere necessary or advisable.[1] The object of this paper is to point out the characters that have been used and others which may advantageously be introduced in the discrimination of the genera of Recent and Tertiary representatives of the group. These are not at present distributed by authors amongst the genera *Rhynchonella*, Fischer; *Acanthothyris*, d'Orbigny; *Hemithyris*, d'Orbigny; *Cryptopora*, Jeffreys (syn. *Atretia*, *Neatretia*); *Frieleia*, Dall; and *Basiola*, Dall.

Surface Ornament.

Buckman in a recent paper[2] divides Jurassic Rhynchonellids into three main series—*Læves*, *Capillatæ*, *Ornatæ*. "*Læves* are smooth and develop ribs directly on a smooth stage; *Capillatæ* have hair-like lines (*striæ*) and then may develop ribs; and *Ornatæ* have additional ornament like imbrication, or spines."[3] In making this statement Buckman cannot be taken to mean that the three series obtained by a consideration of surface ornament are natural groups, equivalent for instance to sub-families, since he has already recognized smooth, ribbed, imbricate, and spinous species in a single genus, *Hemithyris*. Schuchert[4] and others have placed the Recent Japanese spinous species, *Rhynchonella döderleini*, Davidson, under *Acanthothyris* solely on account of the possession of spines, and Buckman has strongly criticized this course. "Spinosity is in itself not a generic character, it is only a stage of development to which various stocks attain. *R. döderleini* can have no connexion with the Jurassic species of *Acanthothyris*; and

[1] Cf. J. Hall and J. M. Clarke, "An Introduction to the Study of the Brachiopoda, etc.": 47th Ann. Rep. New York State Museum, 1894, pp. 1016–17.

[2] S. S. Buckman, "The Brachiopoda of the Namyau Beds of Burmah: Preliminary Notice": Rec. Geol. Surv. India, vol. xlv, pt. i, pp. 75–81, 1915.

[3] "The type of *Rhynchonella*, *R. loxia*, Fischer, is one of the *Capillatæ*. The *acuta* group, which so resembles it, belongs to the *Læves*, and so must be removed. The result is that *Rhynchonella*, which once covered hundreds of species from Ordovician to Recent, must now be confined, so far as present knowledge goes, to one species, *R. loxia*" (Buckman, loc. cit.).

[4] C. Schuchert, Brachiopoda in Zittel, *Textbook of Palæontology*, translated by C. R. Eastman, 2nd ed., 1913, p. 400.

it is more probably a spinous development of *Hemithyris nigricans*."[1] Chapman[2] also speaks of *Acanthothyris squamosa* (Hutton), and here the same argument applies; this species, which is imbricate in ornament, presents all the characters of *Hemithyris*, to which genus it should be assigned. It is probable that *Hemithyris nigricans*, which is coarsely ribbed and not imbricate, is a catagenetic development of a coarsely ribbed, imbricate, Oamaruian (probably Miocene) species, not yet named, which differs from *H. squamosa* in its much coarser ribs, while *H. döderleini* may be a spinous (anagenetic) development of the same imbricate ancestor.

If spinosity is not in itself a generic character, it is still less of sub-family value. Schuchert has used it to separate *Acanthothyris* under the Acanthothyrinæ from the majority of smooth or ribbed Mesozoic and later Rhynchonellids which are placed in the Rhynchonellinæ. Without doubt *Acanthothyris* is a spinous development of one of the Jurassic ribbed stocks distinguished by Buckman, and some other characters must be employed if the Rhynchonellidæ are to be subdivided into natural sub-families.

Types of Folding.[3]

Of the characters liable to variation in the family, one to which few exceptions exist is the more or less strong dorsal uniplication, which finds its greatest expression in *Rhynchonella* itself. In *Hemithyris* this type of folding is present but not always strongly marked, some of the species being almost non-plicate, but the southern fossil forms of the *H. nigricans* series are often strongly folded. Biplication is not known amongst Rhynchonellids, with the exception of *Rhynchonella salpinx*, Dall,[4] an American Eocene form which is narrowly biplicate with two additional lateral folds. This species has not only the type of folding characteristic of *Dallina*, but has also Dalliniform beak characters, and as the internal characters are unknown it is more than likely that it is not a Rhynchonellid, but a Terebratulid in which the pores have been filled up by an unusual process of fossilization.

Ventral uniplication is well marked in the Triassic *Norella*, Bittner, and is incipiently displayed by the Recent *Cryptopora*, Jeffreys. Dall has described under the name of *Hemithyris strebeli*[5] a mid-Pacific abyssal shell which shows clear ventral uniplication, and therefore cannot belong to *Hemithyris*, but must be placed in a new genus.

Neorhynchia, gen. nov.

Genotype *Hemithyris strebeli*, Dall.

Ventrally uniplicate, shell thin, broad, smooth. Beak hypothyrid. Dorsal valve with a thin, thread-like septum, no hinge-plate. Ventral

[1] S. S. Buckman, "Antarctic Fossil Brachiopoda collected by the Swedish South Polar Expedition": Wissensch. Ergeb. Schwed. Südpolar-Exped., 1901–3, Bd. iii, Lief. vii, p. 11, 1910.

[2] F. Chapman, *Australasian Fossils*, Melbourne, 1914, p. 167.

[3] Cf. J. A. Thomson, "Brachiopod Morphology: Types of Folding in the Terebratulacea": Geol. Mag., Dec. VI, Vol. II, pp. 71–6, 1915.

[4] Trans. Wagner. Free Inst. Sci. Philadelphia, vol. iii, pt. vi, pp. 1535–6, pl. lviii, figs. 5–7, 1903.

[5] Bull. Mus. Comp. Zool. Harvard, vol. xliii, p. 441, 1908.

valve without septum, hinge-teeth supported by dental plates. Muscular impressions obscure.

Folding of the *Cincta* type is rare amongst Rhynchonellids, but is exhibited by the Triassic *Halorella*, Bittner. *Frieleia*, Dall, is practically non-plicate, but it seems from Dall's description that there is a faint sinus in each valve.

CHARACTERS OF BEAK AND DELTHYRIUM.

Buckman[1] has introduced the terms 'hypothyrid' and 'epithyrid' to designate two contrasted types of beak characters, a shell being hypothyrid when it exhibits a distinct oval or circular opening below the apex, and epithyrid when it exhibits a truncate perforate beak. The possession of hypothyrid beak characters is an almost constant characteristic of Rhynchonellids, but *Terebratuloidea*, Waagen, and *Peregrinella*, Oehlert, are epithyrid with large foramens. There is a Tertiary series of Rhynchonellids, mostly smooth, which exhibits epithyrid beak characters with minute foramen, and these require generic recognition.

ÆTHEIA, gen. nov.

Genotype *Waldheimia* (?) *sinuata*, Hutton[2] = *Terebratula gaulteri*, Morris.[3]

FIG. 1.—*Ætheia gaulteri* (Morris), Oamaruian, New Zealand: a, holotype of *Waldheimia sinuata*, Hutton, Curiosity Shop, Canterbury; b, interior of posterior part of dorsal valve, showing septum and cardinalia (crura broken), Squire's, South Canterbury.

Dorsally uniplicate. Beak epithyrid, with a minute foramen. Dorsal valve with high socket ridges, and a short stout low septum, rising rapidly posteriorly, fusing with the crural bases and supporting a short cardinal process. Hinge-teeth of ventral valve transversely striated, not supported by dental plates. Muscular impressions small but well marked, posterior, close. The genotype is perfectly smooth.

Buckman has described a smooth Rhynchonellid from the Antarctic Miocene under the name of *Hemithyris australis*, and states that it belongs to the *Rhynchonella bipartita* series, in which he apparently places also *R. bolcensis* (Massalongo) and *R. lucida*, Gould. *R. bipartita*

[1] Ann. Mag. Nat. Hist., ser. VII, vol. xviii, pp. 322–3, 1906.

[2] Cat. Tert. Moll. Ech. New Zealand, 1873, p. 36.

[3] Quart. Journ. Geol. Soc., vol. vi, p. 329, pl. xxviii, figs. 2, 3, 1850. The type of this species is lost, and some doubt may attach to the identification of *W. sinuata*, Hutton, with it. As the internal characters of the genus have been worked out on specimens agreeing with the type of the latter species, it is chosen for the genotype.

(Brocchi) occurs in the Miocene of Malta and Italy, *R. bolcensis* in the Eocene of Italy, and *R. lucida* in the Recent seas of Japan. Whether any of these species belong to *Ætheia* cannot be decided until their internal characters have been examined, and the same applies to the smooth Cretaceous Rhynchonellids such as *R. limbata* (Schlotheim). It may be pointed out, however, that according to Davidson's descriptions[1] the foramens of *R. bipartita* and *R. lucida* are not apical but lie beneath the beak, so that it is quite probable that these species are correctly referred to *Hemithyris*, while on the other hand those of *R. limbata* and of *R. bolcensis* are minute, as in *Ætheia*, and apical so far as the figures can be trusted.

Rhynchonella patagonica, Ihering,[2] from the Patagonian formation, appears to belong to *Ætheia*, for according to Ihering it possesses the minute apical foramen, while the internal characters, so far as can be judged from the figures, agree well with those of the genotype. Ihering had already noticed the peculiarities of the beak, and remarked that he believed that the species should be placed in a different sub-genus. *Ætheia patagonica* is of interest in possessing numerous very fine squamosal ribs, showing that in this, as in other stocks, the ornament cannot be considered a character of generic value.

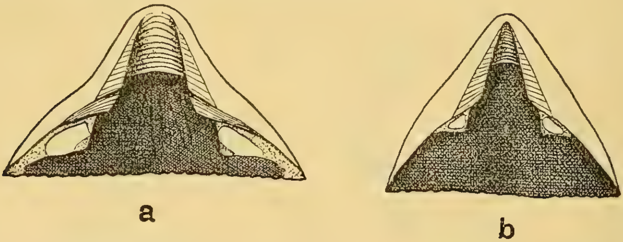

FIG. 2.—Beak of *Hemithyris*, enlarged dorsal view, showing deltidial plates. a, *H. nigricans*; b, *H. psittacea*.

The manner in which the delthyrium of *Hemithyris* becomes partially closed is not well understood. In most recent species, including the genotype, *H. psittacea*, there is a large pedicle opening in front of the beak, margined laterally by two deltidial plates, and in front by the umbo of the dorsal valve. In some Tertiary species the lateral deltidial plates unite at their bases and thus separate a hypothyrid foramen from the dorsal valve, and this is the case also in *Basiola*, Dall.[3] In all cases, however, the deltidial plates are not confined to the dorsal part of the delthyrium, but are reflected down the sides and unite ventrally in a plate which is joined behind to the inner side of the apex, but is free in front and separated from the shell by a narrow cavity (Fig. 2). The pedicle, therefore, is surrounded on three sides by deltidial plates in species of *Hemithyris*

[1] Ann. Mag. Nat. Hist., ser. III, vol. xiv, p. 10, 1864; GEOL. MAG., Dec. I, Vol. VII, pp. 460–1, 1870; Mon. Brit. Foss. Brach., pt. ii, pp. 79–80, 1855; Trans. Linn. Soc. Lond., vol. iv, pt. ii, pp. 168–9, 1887.

[2] Ann. Mus. Nac. Buenos Aires, t. ix, pp. 334–5, figs. 11, *a–b*, 1903.

[3] Bull. Mus. Comp. Zool. Harvard, vol. xliii, p. 442, 1908.

with discrete deltidial plates, and is completely enclosed in a funnel-shaped pseudo-deltidium in those species where the upper deltidial plates unite, including *Basiola beecheri* (Dall). *Basiola* is merely a *Hemithyris* in which the dorsal deltidial plates are united, a difference hardly entitling it to separate generic rank.

Hinge-teeth and Dental Plates.

The majority of Rhynchonellids have hinge-teeth in the ventral valve supported by dental plates. This is the case in all the Tertiary and Recent genera here noticed with the exception of *Ætheia.* In *Hemithyris* the dental plates are slender but quite distinct, and are clearly mentioned in the descriptions of species by Davidson, Dall, and others. Nevertheless the statement is made by Hall & Clarke [1] that dental plates are absent in this genus, and this error has been copied by Schuchert,[2] and has led Buckman [3] to state that *Hemithyris imbricata* is correctly placed under *Hemithyris* on account of the apparent absence of dental plates amongst other characters.[4]

Cardinalia and Septa of Dorsal Valve.

Cardinalia is a new term to embrace collectively the socket walls or ridges, crural bases, hinge-plate, and cardinal process of the dorsal valve. These parts are in some genera so intimately united that they cannot be separately described, e.g. in *Bouchardia.* When a septum is present in the dorsal valve it often unites posteriorly with the cardinalia. The socket-ridges are the processes forming the inner walls of the dental sockets and bearing on their inner sides the crural bases, hinge-plate, etc. They are by some authors confused with the cardinal process, while Dall consistently speaks of them as the hinge-teeth of the dorsal valve but as they do not fit into corresponding sockets in the ventral valve, the other term of King is preferable.[5] A cardinal process, either resting directly on the apex of the valve, or resting on an excavate hinge-plate supported by a septum, or resting directly on the septum itself, is present in probably all the genera of Recent and Tertiary Rhynchonellids. Schuchert[6] uses the supposed absence of a cardinal process to separate some Palæozoic and the bulk of Mesozoic and later genera under the Rhynchonellinæ from the early Palæozoic Rhynchotreminæ, in which such a process is present. There is certainly some misunderstanding here.

[1] "An Introduction to the Study of the Brachiopoda, etc.": 47th Ann. Rep. New York State Museum, 1894.

[2] Loc. cit. [3] "Antarctic Fossil Brachiopoda," etc., p. 11.

[4] It is probable that Buckman's species has slender dental plates, for it appears to be synonymous with *H. squamosa* (Hutton), in which they are certainly present. Hutton gave no figure of the latter species, and his description is meagre. An examination of the holotype shows that the species was misunderstood by Tate, who figured a much broader form under that name, and in this Buckman followed him. *H. cœlata* (McCoy) is a more coarsely ribbed species, while *H. pyxidata*, Davidson, has discrete deltidial plates.

[5] W. King, *A Monograph of the Permian Fossils of England*, 1850, p. 68, pl. xx, fig. 11. Schuchert speaks of these socket walls as hinge-plates, but this is opposed to the usual convention (cf. H. Woods, *Palæontology Invertebrate*, p. 158, fig. 65, *b*, 1902).

[6] Loc. cit.

In *Hemithyris* there is a small ridge separating the muscular impressions of the dorsal valve which might be described as a rudimentary septum. It does not reach posteriorly to the cardinalia. The latter consists of a pair of socket-ridges which spring from the sides of the valve and project obliquely inwards and upwards, at the same time converging posteriorly nearly to a point. They bear the crural bases on their upper inner margin, fused with them for their whole length. There is no hinge-plate. The cardinal process is transverse and deeply embayed in the middle and is supported by the posterior ends of the crural bases at the sides, but rests in its middle part directly on the umbo of the valve.

In *Frieleia* there is a short low slender mesial septum uniting with the cardinalia. The latter consists of two transversely striated socket-ridges diverging at an angle of about 120°, to which the crural bases are attached along their inner sides. To these in turn are attached two hinge-plates, excavate underneath, uniting mesially and resting on the septum. These hinge-plates differ from those of *Magellania* in possessing an embayed instead of a pointed front. On the hinge-plates there is a small cardinal process.

Ætheia resembles *Frieleia* in the presence of a short septum uniting with the cardinalia, but differs in possessing no excavate hinge-plate. The whole space between the socket-ridges from the floor of the shell as far up as the crural bases is solid, forming an elevated floor, and on this the cardinal process is superimposed.

Cryptopora possesses a long septum which is high near its anterior end, but rapidly lessens in height posteriorly until it unites with the cardinalia. Davidson states that a hinge-plate is present, but his figures do not bear this out. There is certainly a cardinal process superimposed on the end of the septum.

In *Neorhynchia* there is a low thread-like septum, perhaps only comparable to the ridge in *Hemithyris*. Dall has not yet figured this species and does not state whether the septum reaches the cardinalia, and mentions no hinge-plate or cardinal process.

Conclusion.

Owing to the small number of genera represented amongst Recent and Tertiary Brachiopods it is possible to present their major differences in tabular form.

	Beak epithyrid. Dental plates absent.	Beak hypothyrid. Dental plates present.		
	Septum low.	Septum rudimentary.	Septum low.	Septum high.
Dorsally uniplicate.	*Ætheia.*	*Hemithyris* (*Basiola*).		
Ventrally uniplicate.		*Neorhynchia.*		*Cryptopora.*
Non-plicate (? *Cincta* folding).			*Frieleia.*	

III.—Studies in Edrioasteroidea, IX. The Genetic Relations to other Echinoderms.

By F. A. Bather, M.A., D.Sc., F.R.S.

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THE last Study brought out many resemblances between Edrioasteroidea and Asteroidea, much closer than have been recognized even by some who have suggested a derivation of the latter Class from the former. In the present Study it is proposed to inquire whether that hypothesis, or any similar hypothesis, is tenable.

Apart from all other considerations, it is clear that, if *Edrioaster* has in its subvective skeleton reached a stage of development higher than that of the older Palæozoic Asterozoa, then it cannot be regarded as the ancestor of these latter. Further, it is hardly conceivable that the earliest Asterozoa known to us were derived from a genus entirely contemporaneous with them. But the Middle Ordovician Edrioasteroidea had, we know, ancestors in the Cambrian, so that the group was probably in existence in Lower Cambrian times, if not before; and it is among those early forms that the ancestors of the Asterozoa must be sought by any who would support the hypothesis under examination. The descendants of those ancient Pelmatozoa exhibited considerable diversity in regard to locomotion, and we do actually find in the Edrioasteridæ forms that have assumed many Asteroid characters. Surely there may have been other descendants with a tendency to similar structures, but adopting a mode of life in which those structures found larger scope for exercise and development. We know, it is true, that similarity of form is in itself insufficient evidence of blood-relationship; and yet there may be something in Mr. Bergson's argument that the independent appearance of similar structures in different groups points to some identity of initial impulse impressed on a common ancestry.

Time-relations, then, admit the possible derivation of Asterozoa from Edrioasteroidea. But of the three main changes involved in such derivation we have as yet only considered two, namely, the change of function in the ambulacra from nutrient to locomotor, and the elaboration of the mouth from a passive funnel to an active predatory organ. These two changes involve no difficulty, but the third, on which they both depend, is less easy to explain. It is the reversal of the main axis of the body with reference to the substratum; in other words, the transference of the oral pole to the under surface.

In a Pelmatozoön the main axis is vertical, the oral pole is uppermost, and around it are the water-ring (from which proceed the perradial canals), the hydropore, the genital aperture (when present), and the anus; the coil of the gut, when viewed from the oral surface, is dextral or solar. In a primitive Holothurian the main axis is horizontal, the oral pole is anterior, and around it are all the above-mentioned organs except the anus, which is posterior; the coil of the gut is the same. In a regular Echinoid the main axis is vertical, the oral pole is lowermost, and around it is the water-ring, from which proceed the perradial canals; the hydropore, the genital apertures, and the anus are at the apical pole; the coil of the gut is the same. The orientation of an Asteroid is essentially the same, except that the genital apertures are marginal, and that the gut is not obviously coiled; the relative positions of the anus, when present, and of the madreporite are, however, in accordance with a solar coil (see *Treatise*, 1900, pp. 21 and 34), and such a coil does appear in early stages of development (Gemmill, 1914). An Ophiuroid differs from an Asteroid in the entire absence of anus, and in the position of the hydropore on the oral surface.

Therefore, the passage from a pelmatozoan to an echinoid or asteroid type involves: (1) the translation of the mouth, the water-ring, and the proximal ends of the perradial water-vessels, from an upper to an under position; (2) the translation of the hydropore, the anus, and, to a less extent, the genital apertures, from the oral to the apical surface; (3) the retention of the solar coil of the gut when viewed from the oral surface. Two modes of effecting the passage are conceivable. The first demands (*a*) the closure of the original mouth and the breaking out of a new one at the opposite pole; (*b*) the corresponding sinking of the circumœsophageal water-ring and the evolution of an entirely fresh set of perradial water-vessels starting from this new oral pole; (*c*) the reversal of the coil of the gut; it does not demand any essential alteration in the position of anus, madreporite, or genital apertures, or in the normal position of the theca as a whole. The second mode demands (*a*) the turning upside-down of the whole theca; (*b*) the migration of hydropore and anus along the posterior interradius towards the aboral pole, and, as a consequence, the elongation of the stone-canal; (*c*) a change in position of the genital apertures; it does not demand any alteration in the original mouth, in the coil of the gut, or in the other relations of the water-vascular system. The position of the genital apertures may be neglected, for in either case there must have been an entirely independent evolution of pentamerism in the gonads, and probably the bursting through of a fresh set of apertures. However this may be, there is little doubt but that the second mode of passage is the more in accordance with general echinoderm evolution. The migration of the hydropore may be paralleled in holothurians, and the migration of the anus in crinoids and echinoids. There remains only the initial step—the overturning of the whole theca.

It is clear that a change of this magnitude was no sudden one. As Professor MacBride has happily remarked, "No animal ever went to bed with one set of habits and woke up in the morning with another." In the absence of direct evidence we can only speculate, but our speculations must be controlled by two distinct sets of facts and principles. The changes imagined must be consistent, first, with the ordinary processes of life and the general character of such changes in the Echinoderma, secondly, with the facts of development in the recent Echinoderma concerned.

A possible mode of origin of Asterozoa from some early Edrioasteroid has been suggested briefly in the *Encyclopædia Britannica*, Supplement, vol. 27, p. 623 (July, 1902) and Eleventh Edition, vol. 8, p. 877

(Feb., 1911), and more fully expressed in "What is an Echinoderm?" (Journ. London Coll. Sci. Soc., vol. 8, pp. 21–33, May, 1901; Italian edition, Oct., 1901). This hypothesis has been criticized on the ground of the structure of certain fossils by Mr. W. K. Spencer (1904), who, however, now recognizes that he "overstated" his "case . . . It is not difficult to imagine a more primitive Edrioasteroid which would show, at any rate, near relationships with the ancestral Eleutherozoa" (1914, p. 6). More weighty objections have been raised by Professor MacBride and Dr. Gemmill on the ground of their admirable observations on Asteroid embryology. But while the hypothesis which they themselves adopt, as expressed in Professor MacBride's *Textbook of Embryology: Invertebrata* (1914, pp. 560–5), is difficult of acceptance, on the other hand some of their own recent observations seem actually to support the hypothesis which they reject. Let us consider these conflicting views more closely.

We now agree on many points of fundamental importance. We agree, namely, that the ancestral Asterozoa were attached by a stem homologous with that of the Crinoidea in so far as it was derived from the same portion of the larva. We agree that the ancestral Asterozoa fed by a subvective system of ciliated grooves. We agree that radiate symmetry was—in Eleutherozoa as in Pelmatozoa—a consequence of this mode of life. It is admitted that processes subsequent to the fixation of the bilaterally symmetrical ancestor by its anterior end eventually brought the stem: (*a*) in Crinoidea, to an aboral position outside the water-ring; (*b*) in Asterozoa, to an excentric oral position within the water-ring. We even appear to be agreed as to the changes that produced the plan (*a*).

The difference arises with regard to the number and order of the steps that produced the plan (*b*).

Whereas some of us have expressed the opinion that the ancestors of the Eleutherozoa passed through a true pelmatozoan stage, with mouth uppermost, and that to this stage the Echinoderma owe their coiled gut and radiate symmetry, MacBride and Gemmill hold that "the Echinoderm stock became split into two stems" shortly after the ancestral Dipleurula had become fixed by its prae-oral lobe, and after the organs of its left side had begun to grow more rapidly than those on the right, but "before the hydrocoel was a closed ring, and before radial symmetry was completely attained". From such a stage, they maintain, the primitive Asterozoön evolved immediately and directly, with its mouth turned towards the sea-floor, so that the left hydrocoel, as it developed into a hydrocircus, grew round the stem, which was therefore on the oral face; and it was while the creature was so supported that radial symmetry was acquired. Figures illustrating this view are given in MacBride's classical paper on "The Development of *Asterina gibbosa*" (1896, Quart. Journ. Micro. Sci., vol. 38, pl. 29, figs. 157–9) and are reproduced in his *Textbook of Embryology* (1914, p. 563). It should be noted that in the *Cambridge Natural History* (1906, Echinodermata, p. 621) a mistake crept into the diagram of the primitive Pelmatozoön, in that the gut was given a contrasolar coil.

It is, presumably, the position of the stalk within the hydrocircus, as observed in the larva of the modern Asteroid, that forms the basis both of MacBride's own hypothesis and of his criticism of the so-called Pelmatozoic Theory. It may, however, be pointed out that in the history of both the Echinoderm race and the Asteroid individual, the hydrocircus begins as a hydrocoel crescent; also that in the larval Asteroid the stalk is on that side of the mouth where the crescent is open, and is not within the circumoral nerve-ring. The passage of the stalk in either direction would therefore be quite easy at a far later period of race-history than that to which Professor MacBride feels compelled to restrict it.

Now the two remarkable features of Echinoderm morphology which any hypothesis should seek to explain are, first, the hypertrophy of the left side with the correlated torsion, secondly, the radiate (normally quinqueradiate) symmetry.

The first of these, which affords the chief reason for the Pelmatozoic Theory, is frankly left unexplained by Professor MacBride. He writes: "It can only be described as an idiosyncrasy of Echinoderms that bilateral symmetry is unstable, and that, therefore, radial symmetry was arrived at by the overgrowth of the organs of the left side, etc." (1914, *Embryology*, p. 562). Similarly Professor Hérouard in an interesting note (Jan., 1915, Bull. Inst. Océanogr. No. 301) describes this "idiosyncrasy" as a hemiplegia, "un phénomène tératologique . . . dont nous constatons l'apparition sans malheureusement pouvoir en expliquer les causes." "On peut dire, que la série des êtres [échinodermales] que nous considérons comme représentant l'évolution normale, n'est dans sa totalité qu'une branche de la tératologie représentant la série des monstres nés viables et capables de se reproduire."

On the supposition that the tendency to this monstrous paralysis of the right side arises from something in the larva itself, the only explanation hitherto suggested has been that of Dr. Fr. Meves (1912, Arch. mikr. Anat., vol. 80, pp. 81–123). Having observed in *Parechinus miliaris* that the middle-piece of the spermatozoön passes at the first cleavage of the spermovum into one of the two blastomeres, he supposes that the substance of the middle-piece is, in the course of successive cleavages, eventually confined to that part of the pluteus which becomes the sea-urchin, and that those parts of the pluteus which disappear consist of cells which, in the course of cleavage, have received none of the middle-piece substance. This hypothesis is merely a succession of uncorroborated assumptions, and even if we could for a moment accept the supposition that the male characters (Vererbungspotenzen) were confined to the embryonic echinoderm, the remaining cells of the larva being merely trophoblast, we should not thereby explain the peculiar changes of symmetry.

Reducing it to its simplest terms, Hérouard (1915) describes the change as the replacement of the original binary axis by a secondary quinary axis. In Asteroidea and Echinoidea, he says, this quinary axis is at right angles to the binary axis. In Ophiuroidea and Holothurioidea, which both MacBride and Hérouard regard as derived respectively from Asteroidea and Echinoidea, the quinary axis is inclined to the binary axis and ends by almost coinciding therewith.

In Pelmatozoa also the quinary axis comes almost to coincide with the binary axis, but its direction is reversed.

Of these changes the Pelmatozoic Theory offers an explanation which, whether correct or no, is at any rate less transcendental than appeals to "idiosyncrasy", invisible "Vererbungspotenzen", or "hémiplexie tératologique". By this theory the relations of the axes of symmetry emphasized by Hérouard are interpreted in accordance with the life-history. The Dipleurula becoming fixed by its anterior end, the mouth passes to the opposite pole, and thus arise the Pelmatozoa with axis vertical and in a reversed direction to that of the Dipleurula. The change from these to the earlier Eleutherozoa is complicated by the retention of the stalk; the whole oral surface bends over, and the quinary axis is at right angles to that of the Dipleurula. In the later Eleutherozoa the process is carried further, and the quinary axis returns almost to the position of the original binary axis.

The associated changes in the torsion of the gut and in the movements of the coelomic cavities, loosely moored in the body-fluids, are described in the *Treatise on Zoology* (1900), and in the writings previously referred to (1901, 1902, 1911). We pass them by for the moment to consider the second morphological feature, the radiate symmetry.

Radiate symmetry arises and is maintained when an organism is evenly related to its environment on all sides. This happens in the case of fixed organisms, when they gather their food from all quarters irrespectively, by leaves or by tentacles or by ciliated grooves; in the case of free organisms, when they move indifferently in the direction of any radius. This evenness of relation may be interfered with from without or from within: from without, especially in the case of a fixed organism, when the situation is such that currents of air or water, or rays of light, beat on it mainly from one side; from within, by some change in the organism itself whereby its relation to the environment is altered, as when a free organism takes to moving in the direction of a particular radius (cephalization), or when a fixed organism for some special purpose (e.g. excretion) enlarges one of its unpaired asymmetrically situate organs. The Echinoderma, which, even in the most specialized Ophiuroid, never have attained an absolute radiate symmetry, present us with examples of almost every conceivable departure from such symmetry in forms both free and fixed.

Now Messrs. Gemmill and MacBride fully accept these views as to the origin of radiate symmetry, and believe with me that the free Echinoderms owe the radiate arrangement of their organs to inheritance from a fixed ancestor, which acquired that arrangement in consequence of the radiate extension of its food-catching organs. But the mode of fixation which they postulate, namely by a stalk asymmetrically placed on the oral face, is not one calculated to lead to such symmetry. Not merely does it appear exceedingly improbable that an animal feeding solely by ciliated grooves should ever have assumed or maintained such a position, but even if it did so it would not have been evenly related to the environment on all sides. In those Pelmatozoa that have assumed a similar position with reference to

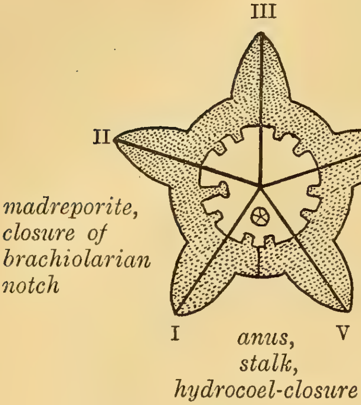


FIG. 1.

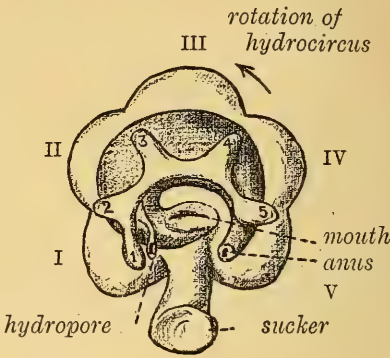


FIG. 2.

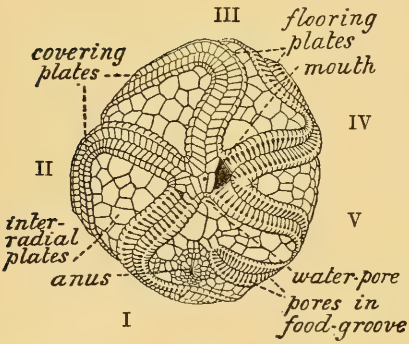


FIG. 3.

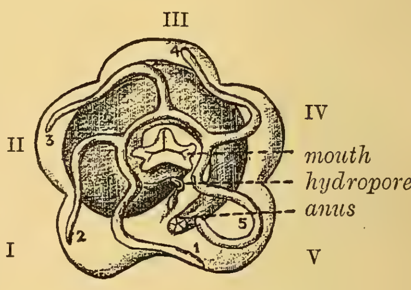


FIG. 4.

FIG. 1.—Diagram to illustrate MacBride and Gemmill's numbering of the rays in Asterias. The view is from the oral side. The position of the anus is that occupied by it in the adult, but it opens on the apical side.

FIG. 2.—Diagram of Asterias at the beginning of metamorphosis, based on the figures and description of Gemmill. The view is from the oral side, on which side the anus opens at this stage. The numbers I–V correspond with II, III, IV, V, I in Fig. 1. Hydrocoel pouches are numbered 1–5.

FIG. 3.—Oral face of *Edrioaster bigsbyi*. The numbers I–V correspond with those in Figs. 2 and 4, but not with those in Fig. 1.

FIG. 4.—Diagram to show the supposed relations of water-vascular system and gut in young Edrioaster. The view is from the oral side. The numbers I–V correspond with those in Fig. 2. The ends of the hydrocoel pouches 1, 2, 3, 4 enter rays 5, 1, 2, 3 respectively, and in this regard make those rays correspond with rays I, II, III, IV of Fig. 1. The hydropore leads into the stone-canal, and probably into a genital duct.

the attachment (e.g. Calceocrinidae) a strong secondary bilateralism has been superimposed on the pentamerism, and has generally quite obscured it. Pentamerism could never have arisen under such conditions.

Another objection to this imaginary ancestor springs from those sanitary principles that have proved so useful in elucidating the morphology of extinct Pelmatozoa (see especially "Caradocian Cystidea from Girvan", §§ 232, 583, 591; Trans. Roy. Soc. Edinburgh, vol. xlix, part 2, No. 6, 1913). The guiding idea is that the excreta should be removed as far as possible from the food intake and the respiratory organs, and at the same time in such a position that they will be carried away by currents. Now the imagined primitive Asterozoön contravenes those principles, because mouth, vent, and hydropore were certainly all on the oral face, and yet we are to suppose that face turned downwards towards the attachment.

Even if the ancestral Asterozoön, as imagined by Messrs. Gemmill and MacBride, could scarcely have been viable, it does not follow that the Pelmatozoic conception of the ancestor is any more in harmony with known facts and principles. Indeed, it is asserted that the facts of recent Asteroid embryology render it inadmissible. Let us consider some of these "very serious ontogenetic difficulties".

A reader who accepts the orientation of the rays adopted in Gemmill's paper on *Asterias rubens* (Phil. Trans., 1914), will speedily meet with stumbling-blocks.

In the larval stages of that form and of several others, the anus, the stalk, and the hydropore all lie between the horns of the hydrocoel crescent. The hydrocircus is formed by the closure of the horns in that interradius. It is therefore from this point that MacBride and Gemmill, very reasonably, start their numbering of the hydrocoel pouches. As the first pouch, they take that which lies towards the anterior end of the bilateral larva: if the embryo star be viewed with the mouth upwards, this is the pouch that forms the left horn of the crescent, so that the remaining numbers follow on in a solar direction. Those authors use the Roman numerals I–V, but, for a reason that will appear presently, it will conduce to clearness if for these particular structures we provisionally use the Arabic figures 1–5. The rays of the star with which these hydrocoel pouches eventually become associated are similarly numbered I–V by MacBride and Gemmill, i.e. ray I corresponds with pouch 1, II with 2, and so on. Thus, for the adult structure, Dr. Gemmill arrives at the annexed diagram (Fig. 1), which is copied from that in his memoir, but turned upside-down so as to render it more easily comparable with the arrangement in Pelmatozoa. Here the adult anus lies in interradius I/V, which marks the "Asterid plane" of Cuénot. It is not in this interradius but in the adjoining one (I/II, solar in oral, contrasolar in aboral aspect) that the madreporite and stone-canal of the adult are found. The latter interradius also corresponds with the brachiolarian notch, and bears a most important relation to the sagittal mesentery of the larva, and to the epigastric mesentery of the developing star.

In all the early Pelmatozoa, on the other hand, the hydropore, the anus, and presumably the closure of the hydrocoel are normally in a single interradius, which bears a definite relation to the branching of the rays, and therefore serves as the starting-point for their numbering.

Now since it is not immediately obvious how either of these sets of organs can have jumped over the intervening radius (I), this seems rather a fundamental difference. It is, I believe, capable of explanation on the Pelmatozoic theory; but before reverting to that let us consider some further facts of embryology.

First, note that in the recent adult starfish both anus and madreporite are on the apical surface. In the early stages, however, they are on the oral surface. Therefore they have migrated. Now while the madreporite remains between the same rays of the star as the original hydropore lay, the anus has changed. We are, however, unable to trace its migration because there is a gap due to closing of the larval intestine and the formation of a new rectum and proctodaeum. This fact alone should be enough to suggest that the evolution of the Asteroidea from the fixed Dipleurula cannot have been so simple and direct as claimed by Gemmill and MacBride and as represented in the latter's diagrams.

As regards the madreporite, the application of these facts to phylogeny is clear, because in the fossils we can trace the historical passage of the madreporite between the rays from an adoral, or oro-marginal, position to an adapical position (see Spencer, 1914, Mon. Brit. Pal. Ast.).

The anus is so obscure, if not absent, that its passage is less easily traced in those fossils. According to C. Schuchert,[1] "The only Paleozoic form in which an anal opening may exist visually is [the Ordovician] *Hudsonaster*. Here it is on the [adapical] disk between the central plate and the madreporite" (p. 13), apparently, then, still in the hydropore interradius; but the anal nature of the appearance is very doubtful (p. 39). In other fossil Echinoderms, however, the migration of the anus can be traced and is observed to follow the presumed line of the coiled gut. That is just what happens in the developing starfish: the coil of the gut shortens and the anus is consequently pulled in a contrasolar direction (as viewed from the oral pole), i.e. from the madreporite plane into the Asterid plane. Though the coil of the gut is thus obscured in Asteroidea, it is important to recognize that it really is of the same nature as in other Echinoderms (see *Treatise on Zoology*, 1900, p. 34).

Consequently, from the embryological and anatomical facts now placed in so clear a light by Dr. Gemmill, we can readily imagine how and why the anus, in its phylogenetic passage from the oral to the aboral surface, followed a course which was not straight but curved so as to bring it into the interradius where it now lies. Further we see that, whereas the anus was exposed to two forces or tendencies, of which its present position is the resultant, the madreporite was subject to only one, namely the tendency to pass

[1] "Revision of Paleozoic Stelleroidea," U.S. National Mus., Bull. 88, 20 March, 1915. This valuable work appeared some months after these paragraphs were first written.

from oral to apical along the straight plane of the stone-canal. Hence it did not change its interradius.

As was shown in "What is an Echinoderm?" these movements are precisely those which would naturally take place on the hypothesis of the origin of Asteroids from such a Pelmatozoön as *Edrioaster*. That hypothesis makes these movements very simple and inevitable, but the converse conclusion does not necessarily follow: the conclusion, namely, that because these movements must have taken place, therefore the ancestor of the Asteroids was an Edrioasteroid. All that is claimed is that the facts thus far are fully consistent with such a conclusion.

We turn now to the next difficulty: the position of the plane of closure of the hydrocoel. As already explained, this plane is placed by MacBride and Gemmill between their rays I and V, i.e. in the Asterid plane of Cuénot (my interradius IV/V).

In the primitive Pelmatozoön, so far as can be inferred from the embryology of *Antedon* and the anatomy of early forms, the closure of the hydrocoel was in what I have termed the M plane (see *Treatise on Zoology*, 1900, p. 20). This corresponds with MacBride and Gemmill's interradius I/II (my I/V).

It is important to notice here that in an Asteroid larva (*Bipinnaria asterigera*) described by Bury, the closure does still take place in the M plane (1895, Quart. Journ. Micr. Sci., vol. 38, p. 65).

Apart from the hydrocoel and its extensions, the food-grooves of Pelmatozoa (which are the initiators of the rays) are bilaterally symmetrical about the M plane. Therefore we are not surprised to find that in Asteroids this same plane is that in which the brachiolarian notch occurs and closes, and that the rudimentary rays (apart from the hydrocoel) are similarly bilaterally symmetrical about that plane (Fig. 2). Other relations of this plane have already been mentioned (see Gemmill, 1914, Phil. Trans., p. 277).

The M plane, therefore, is as fundamentally important a plane for Asteroidea as it is for Pelmatozoa. The Asterid plane is a plane of superimposed symmetry, due to the migration (*a*) of the anus, (*b*) of the hydrocoel-closure. One speaks of the "migration" of the hydrocoel-closure because it cannot be imagined that the closure takes place in a different part of the hydrocircus itself. If we postulate any homology whatever with Pelmatozoa, we can only explain the difference of position by supposing that the whole hydrocoel has shifted round. The extent of the shifting would be one-fifth of a circle, i.e. 72°; and the direction of the shifting, as viewed from the oral face, would be contrasolar. Such shifting need not involve the hydropore, with which the hydrocoel has only a secondary connection.

Now we know very well that, in those Asteroids where the hydrocoel-closure is in the Asterid plane, just such a shifting or torsion does take place in the early stages of metamorphosis. To quote Gemmill (1914, Phil. Trans., p. 251), "the disc undergoes torsion through about 75° in the (starfish) horizontal plane, counter-clockwise as viewed from the sucker." It must be remembered that the development of the lobes of the hydrocoel is quite independent from that of the arms, and that only later on do the two sets become apposed or harmonized. The accounts given by the embryologists seem to prove that in certain Asteroids there actually is such a shifting of the whole hydrocoel that each lobe of it becomes applied, not to the ray to which it would (especially on any homology with Pelmatozoa) naturally belong, but to the neighbouring ray, just as though one were to twist a clock-face backwards, so that when the clock struck twelve the hands should point to twelve minutes past two (i.e. one-fifth of the clock-face).

This interpretation is confirmed by the exception; for in Bury's *Bipinnaria*, where the hydrocoel closes in the M plane, the fusion of the main hydrocoel lobes with the rays "is effected", says Bury, "without that rotation of the two series of organs noticed by Ludwig in Asterina" (1895, p. 68).

It seems legitimate to infer that in some remote ancestor of the Asteroids the closure of the hydrocoel took place in the M plane, and that the lobes 1 to 5 corresponded with the rays numbered I to V in the Pelmatozoa, but numbered respectively II, III, IV, V, I in the adult Asteroid by MacBride and Gemmill.

Why this torsion took place in some Asteroids we do not know. It may have been connected with the migration of the anus and the dragging of the mesenteries. That is a point which the embryologists do not as yet seem to have discussed.

It was, however, pointed out in "What is an Echinoderm?" that if any Asteroids were evolved from a pelmatozoön in which the food-grooves had a strong contrasolar curve (as in *Edrioaster bigsbyi*), then some such contrasolar torsion of the oral region through 72° would naturally accompany the straightening of the rays. Examination of Text-figures 3 and 4 will at once make this clear. This hypothesis works quite well so far as the hydrocoel is concerned, but seems to create a difficulty with regard to the hydropore, which, one might suppose, would also have been involved. We have to remember, however, that the hydropore and stone-canal did not necessarily accompany the hydrocoel, and when the madreporite had attained the aboral surface and escaped the influence of the rays, it might have been pulled back into its original interradius by the stone-canal.

Any exceptions, such as Bury's *Bipinnaria*, would, on this same hypothesis, be readily accounted for by supposing those starfish to derive from an Edrioasteroid like the Cambrian *Stromatocystis*, in which the rays have not acquired a curvature.

To consider the possible relations of the Pelmatozoa (Edrioasteroid or other) to the Echinoidea would unduly prolong the argument. Those to whom the present paper is intended to appeal agree with me that the Echinoidea no less than the Asteroidea must have had a fixed ancestor, and Professor MacBride, for one, would derive all Eleutherozoa from the Asteroid stem. If we can but agree as to the Asteroid ancestor, the rest follows.

The essential difference between us is that Messrs. MacBride and Gemmill believe the Asteroid to have evolved directly, mouth downwards, from the Dipleurula, whereas I would insert a true Pelmatozoic stage.

So far as the change in mode of life is concerned, their hypothesis is no easier than mine. Professor MacBride has made a number of ingenious suggestions, chiefly dependent on "the fundamental distinction which obtains at the present day between the habits of Eleutherozoa, which in the majority of cases are scavengers, devouring dead animals and organic detritus lying on the bottom, and those of Pelmatozoa, which to this day feed on Plankton captured by currents produced by the cilia covering their tentacles" (1914, *Embryology*, p. 564). Now that Dr. Gemmill has broken down the barrier of this "fundamental distinction" the hypotheses based on it lose much of their probability.

If we imagine an Edrioasteroid with loose attachment, liable to be overturned by currents, just as we know that individuals of *Stromatocystis* were overturned, then all we have to suppose is that some of the overturned individuals were able to survive the accident. This they would be able to do if they had fairly well-developed podia, such as are indicated by the anatomical evidence. Even without the overturning, the podia of such genera as *Edrioaster* and *Dinocystis* might have subserved locomotion; for in them the ends of the subvective grooves were brought into almost direct contact with the sea-floor. Indeed, it is hard to see how locomotion could have been avoided.

As for the alleged directness of individual development (which, as already pointed out, is not direct in some important particulars), this may well be more apparent than real. If it be direct, we are thrown back on 'idiosyncrasy' and 'hemiplegia' and misfits 'somehow displaced'. If, on the other hand, the stalk represents the last trace of a former pelmatozoic stage, we have to imagine that the greater part of that stage has been cut out. But what is more natural? In Ophiuroidea the fixed stage is omitted altogether. In Asteroidea it is not omitted but condensed. The later stage, in which the mouth is already directed downwards, has been pressed back so as to eliminate the supposed stage during which it passed upwards. The preservation of that stage in the ontogeny would have been a useless waste of energy.

Dr. Gemmill says that my view introduces "very serious ontogenetic difficulties". I am unable to see that the main ontogenetic difficulties are any better explained by the Gemmill–MacBride theory, which in its turn seems to me to introduce a fresh set of phylogenetic difficulties.

IV.—The Moraine Walls and Lake Basins of Northern Italy.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

The present paper is the outcome of a number of visits which, during a prolonged professional residence in Italy, I paid to Piémont, Lombardy, and the Italian lakes, and in the course of which I became familiar with the glacial phenomena and the lake basins along the southern base of the Alps.

It is forty years—1874 to 1876—since the 'Moraine Amphitheatre', or series of moraine walls at the foot of the Italian Alps, suddenly came into prominence through the discovery, chiefly by Stoppani, of several glacial clay, sand, and gravel deposits in the vicinity of Como, which contained marine shells, and therefore demonstrated the presence of the sea in contact with the Alpine glaciers. Stoppani's conclusions, expounded in two brilliant memoirs,[1] were endorsed not only by his Italian confrères, Spreafico[2] and Sordelli,[3] but also by distinguished geologists north of the Alps, notably by Désor of Neuchâtel,[4] Renevier of Lausanne,[5] and Rutimeyer of Bâle,[6] the revealing memoirs more especially of the two last-named being models of classical and closely reasoned exposition. Since then the subject has been enlarged upon chiefly by discoveries of interglacial deposits in various sub-Alpine valleys debouching into the Lombardy plain, and more recently Penck and Brückner have dealt with it from their point of view in their latest monumental work,[7] whose salient features have been summarized by G. W. Wright.[8] But the evidence adduced by the various Italian and other writers, including Penck's somewhat laboured endeavour to work out his four glaciations for the Alps *en bloc*, is as yet so conflicting that it is almost refreshing to turn to the earlier and more conclusive views of Stoppani and his contemporaries as a point of departure for considering the subject *mutatis mutandis*, in order to arrive at some independent conclusions from personal observation.

I. The Moraine Walls.

As will be seen from the sketch-map, Sheet No. 1, Fig. 1, the belt of double, in many places triple concentric moraine walls which fringes the southern base of the Alps, forms roughly a semicircle extending from Cuneo in the south of Piémont to Lake Garda in Lombardy, a distance of about 400 kilometres, and from the last-named point to the Frioul, another 200 kilometres. The most striking feature of this belt consists not only in its remarkable extent but in the enormous accumulations of glacial material, compared with which the morainic deposits north of the Alps, notably in Switzerland, almost sink into insignificance. The moraine walls were all formed, like so many bars, in front of the exits of the principal valleys. Thus, near Cuneo we find the terminal moraine of the Stura glacier; west of Savigliano, that of the Po (Monte Viso); at Rivoli, near Turin, that of the Dora

[1] Stoppani, "Il mare glaciale ai piedi delle Alpi": Rivista Italiana, Agosto, 1874. "Sui Rapporti del terreno glaciale col Pliocenico nei dintorni di Como": Atti Soc. Ital. di Scienze naturali, Aprile, 1875.

[2] Spreafico, "Conchiglie marine nel terreno erratico di Cassina Rhizzardi (Fino, Prov. di Como)": Atti Soc. Ital., 1874.

[3] Sordelli, "La Fauna marina di Cassina Rhizzardi, Fino": Atti Soc. Ital., 1875.

[4] Désor, *Le Paysage morainique et son origine glaciaire*, Neuchâtel, 1875.

[5] Renevier, "Rélations du Pliocène et du Glaciaire aux environs de Côme": Bull. Soc. Géol. France, sér. III, tome IV, 1876.

[6] Rutimeyer, *Ueber Pliocän und Eisperiode auf beiden Seiten der Alpen*, Bâle, 1876.

[7] Penck and Bruckner, *Die Alpen im Eiszeitalter*, 1909.

[8] G. W. Wright, *The Quaternary Ice Age*, 1914.

Riparia (Mt. Cenis); at Ivrea that of the Dora Baltea (Mt. Blanc and Mt. Rosa); at the lower end of Lakes Maggiore and Varese, that of the Ticino and Toce (St. Gothard and Simplon); near Como and Lecco that of the Adda; at the lower end of Lake Isco that of the Oglia; and at Lake Garda the terminal moraine of the Mincio glacier.

The most formidable of these moraine walls are those of Ivrea and at the lower ends of Lakes Maggiore, Como, and Garda. South of Ivrea the Monte Rosa glacier, descending through the lower Dora Baltea Valley, has left two stupendous marginal moraine walls, the "Serre" of Andrate and Brosso, which reach a height of no less than 450 metres above the present river-level and, with the frontal moraine broken up into hillocks and interspersed with morainic lakelets, form a circumference of at least 50 kilometres. Again, south of Lakes Maggiore and Varese, the concentric moraine belts of the Ticino and Toce glaciers extend to 10 kilometres from the lake-end, with a circumference of 50 kilometres and a height of 150 metres above Lake Maggiore. South of Como the moraine deposits form, in a distance of barely 10 kilometres, three separate concentric ridges about 20 kilometres in length, rising to 152, 157, and 165 metres above the level of Lake Como. Similarly, at the lower end of Lake Garda, the moraine walls extend in concentric semicircles and an extraordinary agglomeration of morainic hills 12 kilometres into the Lombardy plain, with a circumference of at least 30 kilometres, and rising to 23, 62, and 141 metres above the lake-level.

The points where marine shells were found embedded in glacial deposits are situated about 6 kilometres south and north-west of Como; the former near Fino, on the second of the three concentric moraine ridges, about 160 metres above the present lake-level, and the latter between Chiasso and Mendrisio in the Breggia Valley, by which the former Lugano fiord communicated with that of Como.[1] The most northerly of the latter deposits is that of Pontegana, near Balerna, about 90 metres above the present lake-level, which, being glacial clay, corresponds to similar deposits near Varese and to others in the Ivrea district. In Lombardy the shell-bearing deposits rest directly on Pliocene marl and are overlain by morainic material of sand, gravel, and conglomerate, known as ceppo and ferretto, while in Western and Southern Piémont many of the glacial deposits exhibit intermediate fluvio-glacial alluvia, whose origin was at the time a subject of keen controversy between Stoppani and Gastaldi. These alluvia are, in fact, the southern equivalent of the "alluvion ancienne" and Deckenschotter north of the Alps, and, as such, the product of a pre-maximum glaciation which in Upper Piémont, but not in Lombardy, reached to the foot of the Alps. As regards the stupendous Moraine Amphitheatre of Piémont and Lombardy as a whole, it can only be the product of the maximum glaciation, while any pre-maximum, as also the post-maximum or last glaciation, probably did not descend much beyond the heads of the present lakes, or, roughly, beyond a limit 30 to 40 kilometres distant from the Lombardy

[1] Most of these deposits are now obliterated, but ample specimens of the marine shells are preserved in the Geological Museum of Milan.

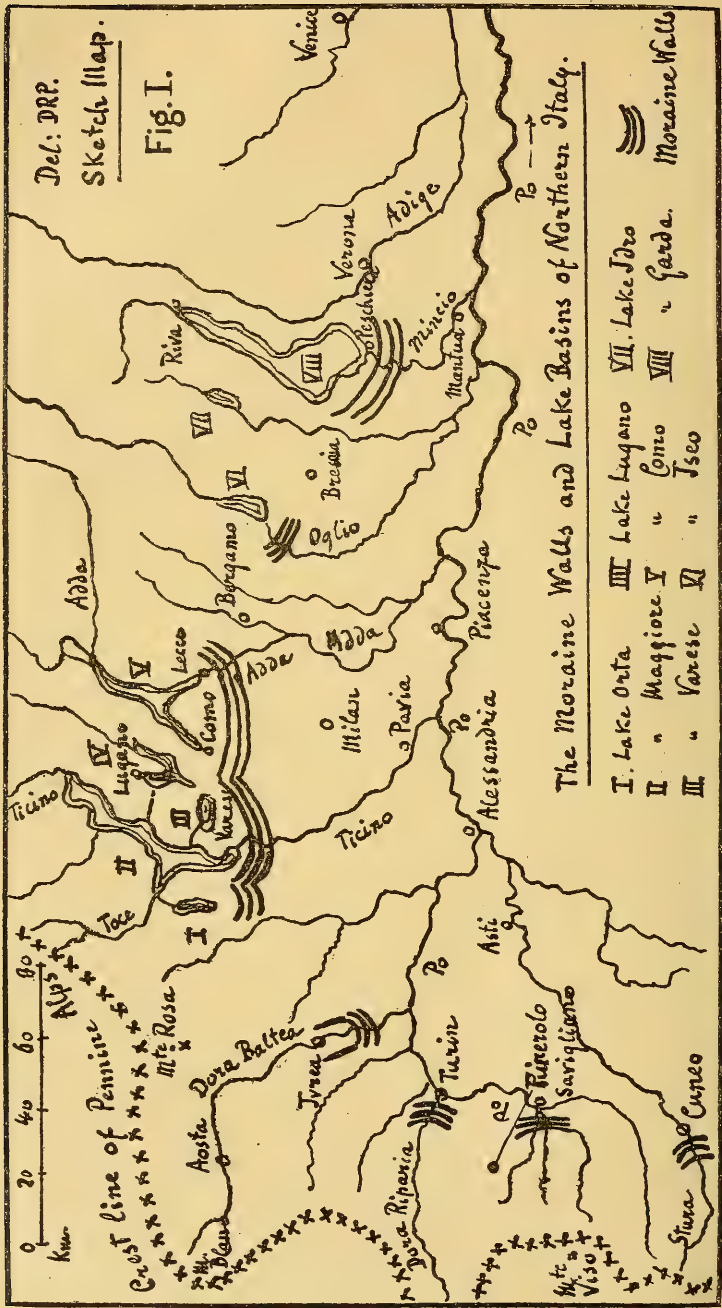
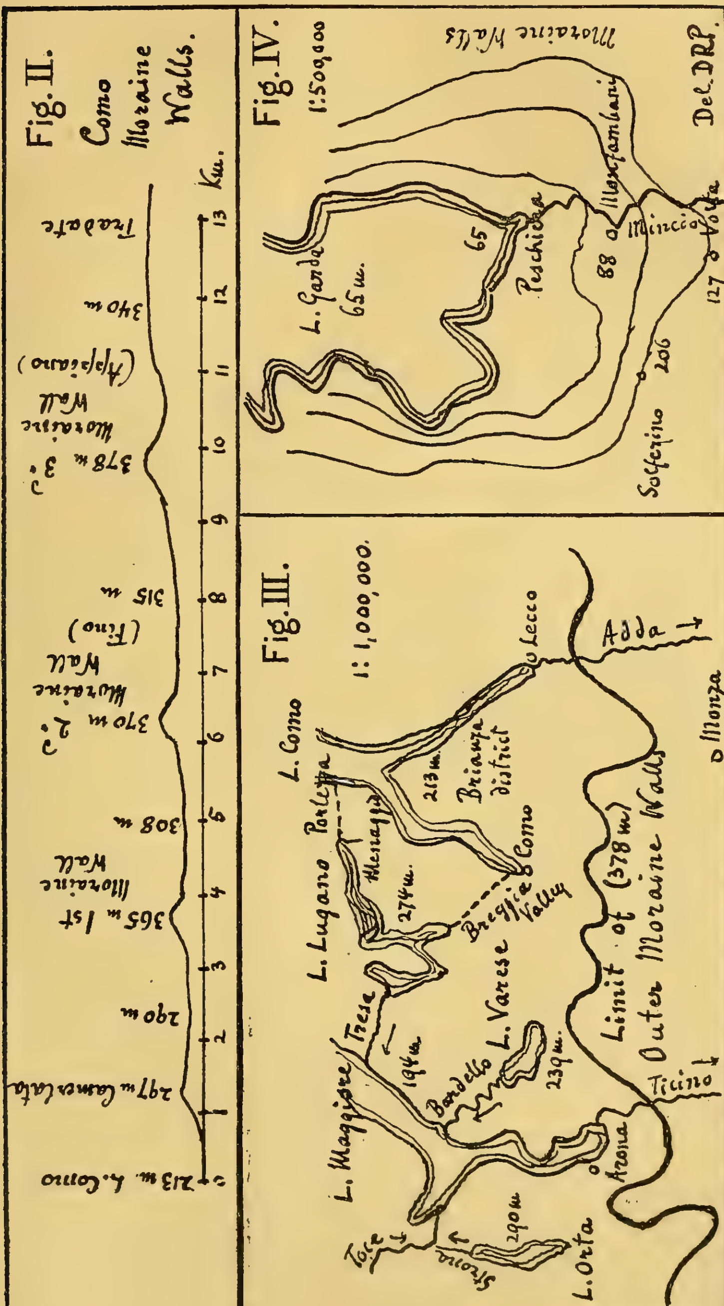


Fig. I.—Sheet No. 1. Sketch-map of Northern Italy.



FIGS. II, III, IV.—Sheet No. 2. Moraine Walls.

plain.[1] The extreme limit of the maximum glaciation, as indicated by the outermost moraine walls 10 to 12 kilometres south of the lower ends of the Lakes Orta, Maggiore, Como, and Garda, is shown in Sheet No. 2, Figs. II, III, and IV.

II. The Glaciers and the Sea in the Po Valley.

The maximum glaciation south of the Alps presents a striking contrast to that on the north in that it was marked by a uniform general advance of more or less self-contained glaciers of the fan or Piémont type, which invaded the Po Valley to a distance of 10 to 12, in the case of the Dora Baltea (Ivrea) glacier even 20 kilometres, while north of the Alps the glaciers spread all over the Swiss lowlands and deposited their terminal moraines even beyond. Thus the maximum length of the southern glaciers, measured from the crest-line of the Alps to their terminal moraine walls, does not exceed 100 kilometres, while on the north the Rhone and the Rhine glaciers, extending beyond the Jura and Lake Constance respectively, reached a length of 300 kilometres, or three times as much. Inversely, the quantity of material carried and deposited by the southern glaciers having an average fall of 1 in 100, was immensely greater than that of the northern glaciers, the average fall of which was only about half the above. Hence the enormous accumulations of glacial material in Piémont and Lombardy, where, moreover, the glaciers on emerging from the valleys were arrested by the sea as an effectual barrier to their further advance into the Po Valley. This Upper Pliocene sea, an arm of the Adriatic, must have lasted well into the Pleistocene period, and the glaciers washed by it must have been stationery for a very long lapse of time, as is shown by the double and triple concentric frontal moraine walls, each of which marks a long halt in the slow retreat of the ice.[2] No less certain is it that the sea must have been at a level much higher than the present Po Valley, and higher even than the present levels of the lakes, for the Pontegana marine shell-bearing deposit in the Breggia Valley north of Como is at 300 metres altitude, which is 87 metres above Lake Como, 197 metres above Milan, and 240 metres above the Po at Piacenza, while the Fino deposits south of Como are at an altitude of even 370 metres. It is therefore obvious that at the advent of the maximum glaciation, arms of the sea reached as far as the fjords which constitute the present lake basins—a phenomenon which has an important bearing on the age and origin of the lakes themselves.

[1] The principal localities of interglacial deposits between Lakes Maggiore, Lugano, and Garda, and beyond are the following: at Re, in the Vigezzo Valley, east of Domo d'Ossola; at Calprino, near Lugano; at Leffe and Gandino in the Seriana Valley, north of Bergamo; at Pianico in the Oglio (Lake Isco) Valley; at Valmarino in the Piave Valley, north of Treviso; in the Tagliamento Valley, north of Udine; and in the Isonzo Valley, north of Gorizia.

[2] It is a striking feature that, of the moraine walls, those of the Como district are continuous, because the Adda eroded its bed marginally from the Lecco arm of the lake, whereas the rivers of Ivrea, Lake Maggiore, and Lake Garda (Dora Baltea, Ticino, and Mincio) found their exit more through the centre of the frontal moraines, which are therefore broken up into agglomerations of hillocks.

III. The Lake Basins.

The following table gives the altitudes and dimensions of the principal six Italian lake basins, which, it will be observed, lie in a zone similar to that of the five Swiss lake basins north of the Alps.

Lake.	Altitude. m.	Length. km.	Mean Width. km.	Area. sq. km.	Greatest Depth. m.	Exit River.
Orta	290	12	2	20	300	Strona [a]
Maggiore	194	60	4	212	372	Ticino
Varese	239	9	2	14	380	Bardello [b]
Lugano	274	22	2	83	300	Tresa [c]
Como and Lecco	213	48	3	144	409	Adda [d]
Isco	201	25	2	62	600	Oglio
Garda	65	55	6	490	346	Mincio

[a] Drains into Toce, affluent of Lake Maggiore; [b] drains into Lake Maggiore; [c] ditto; [d] exit through Lecco arm.

It will be seen that not one of these lakes reaches the altitude of 300 metres, which, as previously shown, is that of the marine shell-bearing deposit a few kilometres north of Como, nor the altitude of the Fino deposits (370 metres) on the second moraine wall south of Como. The sea in the Po Valley must therefore have communicated with the fjords at a level much higher than that of the present lakes.

The question of how and when the present lakes were formed is obviously and closely allied with the retreat of the sea from the Po Valley. Désor[1] held that from the time of the glaciers coming into contact with the sea the littoral of the Lombardy and Piémont plain was gradually raised; but this would only account for the high level of the Fino and the other marine shell-bearing deposits. It appears much more likely that a simultaneous lowering took place on the one hand in the floor of the Po Valley,[2] while the sea gradually receded, and on the other along the base of the Alps, which converted the fjords into lakes in addition to the fjords being choked by the moraine bars of the retreating glaciers. The formation of the lakes would, therefore, be due to the same two concurrent causes which operated in the formation of the lake basins north of the Alps—a zonal flexure and a moraine barrier behind which the river valleys or fjords became lakes during the recession of the glaciers.

The cross-section of the triple moraine walls south of Como shown in Sheet No. 2, Fig. II, which Rutimeyer gave for another purpose in his memoir already quoted, exhibits a striking reverse dip from the outermost wall to Lake Como of no less than 165 metres. The third moraine wall, which rests upon considerably bent strata of Molasse, thus constitutes, in my view, the anticline of the flexure whose syncline to the north follows the deepest points of the lakes, while the syncline to the south lies along the lowered floor of the Po Valley. The conditions in respect of Lake Maggiore and of Lake Garda are precisely similar, the reverse dip to the former being 150

[1] *Paysage morainique*, p. 72.

[2] The deposition of the rich alluvia which cover the floor of the Po Valley, and to which it owes its wonderful fertility, began with the retreat of the glaciers when the rivers resumed their erosive energy, and continued throughout the long interglacial period after the maximum glaciation.

and to the latter 140 metres. The two last-named lakes afford, moreover, at their lower ends, typical examples of the formation of lake basins behind the terminal moraines of retreating glaciers, for in both cases the widened basins at the lower ends are appendages of the original fjords, and their contours conform strikingly to those of the concentric moraine walls behind which they were formed.

The zonal flexure also accounts for the extraordinary depth of the present lake basins as the result of overdeepening by the lowering of their floors, as against the theory of overdeepening by the direct action of glacial erosion, as if such steep, long, and narrow basins could be formed by the vertical scooping of a glacier in the same way as a cirque or corrie. The indirect action of the glaciers was more probably confined to the widening of the fjords and of the tributary valleys of the Dora Baltea, Ticino, Adda, and others.

The simultaneous operation of the zonal bending and the retreat of the glaciers on the one hand, and the recession of the sea from the Po Valley on the other, must have been of very long duration, probably till the end of the Ice Age, including the period of the last glaciation, which did not reach, and therefore did not directly affect, the contact zone of the sea and the moraine walls in the Po Valley.

Such extraordinary phenomena as the natural exit of the Como fjord being choked and its drainage reversed, so that the present lake has its only exit through the Lecco arm; or the former connexions between the Como and Lugano fjords at Menaggio and Porlezza, and through the Breggia Valley at Chiasso being severed by the lowering of fjord levels, and the Lugano fjord finding its exit through the Tresa into Lake Maggiore; or again, Lake Orta having its southern outlet barred and its drainage reversed to the north into the Toce; or, similarly, Lake Varese draining reversely into Lake Maggiore,—all these phenomena, as well as the labyrinth of erratic and tortuous watercourses throughout the morainic littoral and the whole lake district, are only some of the direct and indirect effects of that great maximum glaciation which has left its impress along the base of the Italian Alps both in Piémont and Lombardy by a morainic landscape in magnitude, grandeur, and variety unequalled in any other part of the Alps or of Europe.

V.—On the Evidence as to the Geological Structure of Cumberland bordering the Solway.

By T. V. Holmes, F.G.S., F.R. Anthrop. Inst.

(PLATE XIV.)

WHILE no doubts have existed among geologists that the rocks of this district are of Permo-Triassic age, that they are surrounded by older formations of the Carboniferous Series, and capped by a small Lias outlier, unanimity as to the relations of the local Permo-Triassic rocks to each other has never yet prevailed. Hence when the Geological Survey Memoir, by the present writer, on this district was published in 1899, Sir Archibald Geikie stated in the preface that the delay in its appearance was due to the hope that additional deep borings might have settled certain questions as to the relations to each other of the rocks above the St. Bees Sandstone, etc. On this account, my own views (as those of the worker on the Geological Survey in this district) were allowed to be given by me in a paper read at the Geological Society in 1881, on "The Permian, Triassic, and Liassic Rocks of the Carlisle Basin" (Q.J.G.S., vol. xxxvii, May, 1881).

The difficulties preventing any thorough settlement of the question of the relations of the Triassic rocks overlying the St. Bees Sandstone to each other arise from the surface of North Cumberland being so much covered by Glacial Drift, alluvium, and other superficial beds. In the belt of ground near the boundary-line between the Permo-Triassic and Carboniferous formations the St. Bees Sandstone may be seen here and there in the banks of rivers, or in quarries, where the overlying drift is thin, though it is seldom wholly absent. But nearer the Solway, north of a straight line drawn from the coast between Maryport and Allonby to Carlisle, and west of the Eden, the surface is wholly covered by superficial beds of various kinds. And along the coast, from the spot just mentioned to Silloth, Bowness, and Carlisle, may be seen expanses of raised beach, blown sand, and other recent deposits, but no rocks of Permo-Triassic age appear except at Rockcliff, north of the Eden, and near its mouth. The Lias outlier, west of Carlisle, forms a plateau entirely veiled by Glacial Drift, so that the only sections showing Lias are very few and small, in the banks of tiny streams. Near Bowness, on the Solway, a boring showed the surface beds to consist of 41 feet of Glacial Drift. Southward, near Abbey Town, a boring showed the surface beds to be 12 ft. 6 in. of alluvial clay above 186 feet of Glacial Drift (Geol. Surv. Mem.).

The boring near Bowness was made in the year 1809; that near Abbey Town between November 14, 1875, and May 18, 1876. But for these two borings the existence of hundreds of feet of Gypseous Shales lying upon the St. Bees Sandstone, in this district west of Carlisle, would be unknown. In the Bowness boring were found (beneath the Glacial Drift) 367 feet of Gypseous Shales; and in the Abbey Town boring 734 ft. 6 in. of them above St. Bees Sandstone, in which the boring ended. Eastward of Bowness and Abbey Town, the late R. B. Brockbank, the discoverer of the Lias in Cumberland, kindly obtained for me a brief record of a boring at Orton, in the Lias area, made in the year 1781 (Mem., p. 22). This boring was for coal, the dark Lias shales having been mistaken for Coal-measures down to a much later date. At the surface were three fathoms of drift, then were found stones, "mostly bluish," and evidently Liassic, to a depth of 38 fathoms, and then "red stone or clay sometimes mixed with veins of white till they came to 60 fathoms". The evidence of the Bowness and Abbey Town borings thus decidedly suggests the presence of at least 22 fathoms of Gypseous Shales beneath the Lias at Orton, as the information obtained from the Orton boring.

East and north-east of Carlisle, in a country less invariably drift-covered than the district westward, is seen the soft, red, false-bedded Kirklinton Sandstone. It is best seen in the River Line, at and north of Kirklinton, and is there the formation resting on the St. Bees Sandstone, though no clear sections appear at their junction. But in Carwinley Burn, which falls into the Esk north of Netherby, the line of junction of the St. Bees and Kirklinton Sandstones is clearly shown, and the unconformity between them unquestionable (Mem., p. 30). To the south-west of the above-mentioned places the Kirklinton Sandstone may be seen at Rockcliff and Cummersdale. But, west of the Eden, its boundary-line is hidden by the persistent nature of the drift covering the surface there, mentioned when treating of the Gypseous Shales. In the Memoir I have suggested that probably the boundary of the Kirklinton Sandstone under the Lias plateau may be the prolongation of a certain line of fault westward. Anyhow, the evidence of the old Orton boring seems to indicate the presence of at least 132 feet of Gypseous Shales there beneath 210 feet of Lias. It seems highly probable that the Kirklinton Sandstone, whether bounded, west of Carlisle, by a fault or not, does not extend beneath the Lias outlier so far westward as Great Orton.

Above the Kirklinton Sandstone, north of Carlisle, are seen the Stanwix Shales, which are mainly red and greenish-grey in colour. They are surrounded on all sides by the Kirklinton Sandstone, the junction between the two formations being well shown at Westlinton and near Cliff Bridge, Kirklinton. The Stanwix Shales may be seen also near Stanwix, north of Carlisle. At Carlisle the evidence from various sections is that "they rise gently southward between Etterby Scaur and Carlisle, and rapidly thin away to nothing at and west of that city". Also that "South of Beaumont there is no evidence as to the exact spot at which the Stanwix Shales abut against the Lias" (Mem., p. 35).

The Lias outlier, though covered by drift, forms a plateau having a boundary-line which, though somewhat vague in consequence of being veiled by its comparatively thin drift covering, yet is everywhere more or less distinctly noticeable. Hence there is a means of approximately ascertaining the boundary of the Lias which does not exist in the case of older formations, west of Carlisle, where the ground is not only more thickly drift-covered but the surface features consist of ridges of Glacial Drift, alluvial flats or peat-mosses.

We have now to consider the evidence bearing upon the comparative ages of the two formations resting upon the St. Bees Sandstone. These are the Gypseous Shales of the Bowness and Abbey Town borings, west of Carlisle, and the Kirklinton Sandstone north-east of the area occupied by the Gypseous Shales. For, as we have seen, there are no sections and no deep borings to settle the question. It always seemed to me that in all probability the Gypseous Shales were the older formation, as their thickness at Abbey Town and Bowness suggested that they occupied an area not only broader than that covered by the Kirklinton Sandstone but one attaining a much greater depth. And while the Gypseous Shales must have been deposited in a lake or lagoon, sandstone would be formed in a shallow and variable area. Then the junction of the

St. Bees and Kirklinton Sandstones in Carwinley Burn (Mem., p. 30) showed the Kirklinton Sandstone to be resting unconformably on that of St. Bees; while the narrow belt of country occupied by the St. Bees Sandstone, at the north-eastern end of the Carlisle Basin, between Carwinley Burn and the River Line, contrasts so strongly with the much broader areas occupied by it around Wetheral and Brampton as to suggest a very decided unconformity between the two sandstones.

In short, the Kirklinton Sandstone seemed to me (like the still narrower and thinner Stanwix Shales overlying it) to be in all probability confined to the north-eastern end of the Carlisle Basin, while the Gypseous Shales occupied a much wider space. And having been formed in a lake basin, and not in a shallow and irregular area, were much more likely to be an older formation than the Kirklinton Sandstone resting unconformably on that of St. Bees.

Since the publication of the Geological Survey Memoir I have not heard of any additional deep borings near Carlisle or in North Cumberland. But when "The Structure of the Carlisle–Solway Basin and the Sequence of the Permian and Triassic Rocks", by Professor J. W. Gregory, was discussed by the Geological Society, April 29, 1914, Mr. G. W. Lamplugh pointed out that "the westward prolongation of the Triassic basin of Cumberland had been proved in several borings in the north of the Isle of Man". He added that he had examined the cores of these borings, and that "they indicated the presence of at least 700 or 800 feet of gypsiferous and saliferous Keuper marl resting upon the St. Bees Sandstone, some hundreds of feet thick, below which there was a thin and inconstant series of Permian marl and sandstone with Brockram" (Abstracts of Proc. Geol. Soc., May 7, 1914).

The above evidence of Mr. Lamplugh is evidently most valuable in favour of the view that the Gypseous Shales of the Abbey Town and Bowness borings should rank as the formation immediately above the St. Bees Sandstone. On the other hand, the Kirklinton Sandstone, which rests unconformably on the St. Bees Sandstone in the north-eastern corner of the Carlisle Basin, and the Stanwix Shales overlying it, are formations confined to that district, and simply illustrate the local irregularities of the Permo-Triassic rocks. The resting of the Lias outlier partly on the Gypseous Shales, and partly on the Kirklinton Sandstone and on the Stanwix Shales, where the two formations last-named are thinning away to nothing, is surely nothing startling to our notions of the possible in the matter of this local position of the Lias. For with rocks like the Triassic, formed in areas so varied in their space and nature as those of Cumberland and the Solway especially are, we should surely be prepared to meet with local irregularities of this kind. For instance, in the discussion on Professor Gregory's paper at the Geological Society's meeting last year, Professor O. T. Jones remarked that in parts of South Wales "the Lias rested upon Carboniferous Limestone, but that was after the various subdivisions of the Trias had been overlapped in succession".

We may now turn from the beds overlying the St. Bees Sandstone to that rock itself and to the Permo-Triassic formations underlying it. They extend not only around Carlisle but up the Eden Valley as far as Kirkby Stephen, and are seen on the coast of Cumberland and Westmorland from St. Bees Head southwards. But those on the coast do not here concern me, nor do the beds of the Eden Valley demand more than the briefest mention.

In the Eden Valley district, for some miles from Wreay southward, there are three formations in the following order:—

St. Bees Sandstone.
Gypseous Shales.
Penrith Sandstone.

But north of Wreay and Cumwhitton, south-east of Carlisle, lines of fault cut off these Gypseous Shales with the underlying Penrith Sandstone, while the St. Bees Sandstone overlaps them and is the only one of the three formations to be seen north of these lines of fault in Cumberland. North of the Solway St. Bees Sandstone appears, near the shore, as far west as Annan. West of Annan may be seen Lower Carboniferous rock. And from Caerlaverock Castle, up Nithsdale, is another Permo-Triassic district, the conspicuous rock between Caerlaverock Castle and the town of Dumfries much resembling the Penrith Sandstone.

We have thus in the country bordering the Solway three districts of Permo-Triassic rocks—that of Nithsdale on the north-west, that of the Eden Valley on the south-east, and the Carlisle Basin in the centre. The last-named, extending, as we now know it does, from the information given by Mr. Lamplugh as to the deep borings in the Isle of Man, evidently occupies much the broadest area.

We are here concerned only with the Carlisle Basin. The lowest of the Permo-Triassic rocks forming this Basin is the St. Bees Sandstone, though possibly very deep borings might reveal the existence of fragments of still older Permo-Triassic rocks beneath it, here and there, as in the north of the Isle of Man. North of the junction with the Eden Valley series, near Wreay, the St. Bees Sandstone is the oldest Permo-Triassic rock visible in Cumberland. From Maryport to a point south of Wigton it rests on Coal-measures, and thence to Wreay on Lower Carboniferous rocks. Then the lines of fault already mentioned separate it from the Permo-Triassic rocks of the Eden Valley, and eastward and northward it rests upon Lower Carboniferous beds, both on the Cumberland side of the Border and north of the Solway as far west as Annan. From Annan towards the south-west it is beneath the level of the sea. Its dip between Maryport and the Caldew usually varies from north to north-west. Between the Caldew and the Hether Burn it slowly changes, being about south-west at the latter stream. North of the Solway it becomes more or less east of south. West of the Esk and at Annan it is nearly due south.

It has always appeared to me that (as just stated) the St. Bees Sandstone is the lowest Permo-Triassic formation forming the Solway Basin, though it is possible that (as in the Isle of Man) a thin and inconsistent series of fragments might be detected here and there, by deep borings, of still older Permo-Triassic beds than the St. Bees Sandstone. In the opinion, however, of Professor Gregory (both as expressed at the meeting of the Geological Society on April 29, 1914, and in the GEOLOGICAL MAGAZINE for June, 1915, in his paper on "The Solway Basin and its Permo-Triassic Sequence"), the Solway Basin should be treated as being practically non-existent. In the GEOLOGICAL MAGAZINE he remarks that it "cannot have such a simple synclinal structure, for Carboniferous rocks occur at the surface near the northern shore of the Eastern Solway". Then follow interesting details of a boring for coal at Redkirk, all the rocks pierced being Carboniferous. And he considers the outcrop of Carboniferous rocks at Redkirk "opposed to the synclinal theory of the Solway", and adds that the existence of the St. Bees Sandstone in North-Western Cumberland "deep below a thick sheet of Gypseous Shales, rests on slender grounds which appear untenable". Having been over the whole district, and having traversed not only the roads but a very large number of the fields, and examined the banks of the various streams, I must reply that there is certainly sufficient evidence as to the existence of the St. Bees Sandstone where it is shown on the geological map. And that the deep borings showing the Gypseous Shales above it in Cumberland have now the additional support of the evidence of Mr. Lamplugh as to the deep borings in the north of the Isle of Man, which also show Gypseous Shales above St. Bees Sandstone. The result of deep borings since I was at work in Cumberland has therefore been simply to show the much greater range of the Carlisle Basin, and its greater importance as a geological feature of the Permo-Triassic rocks there than I had anticipated.

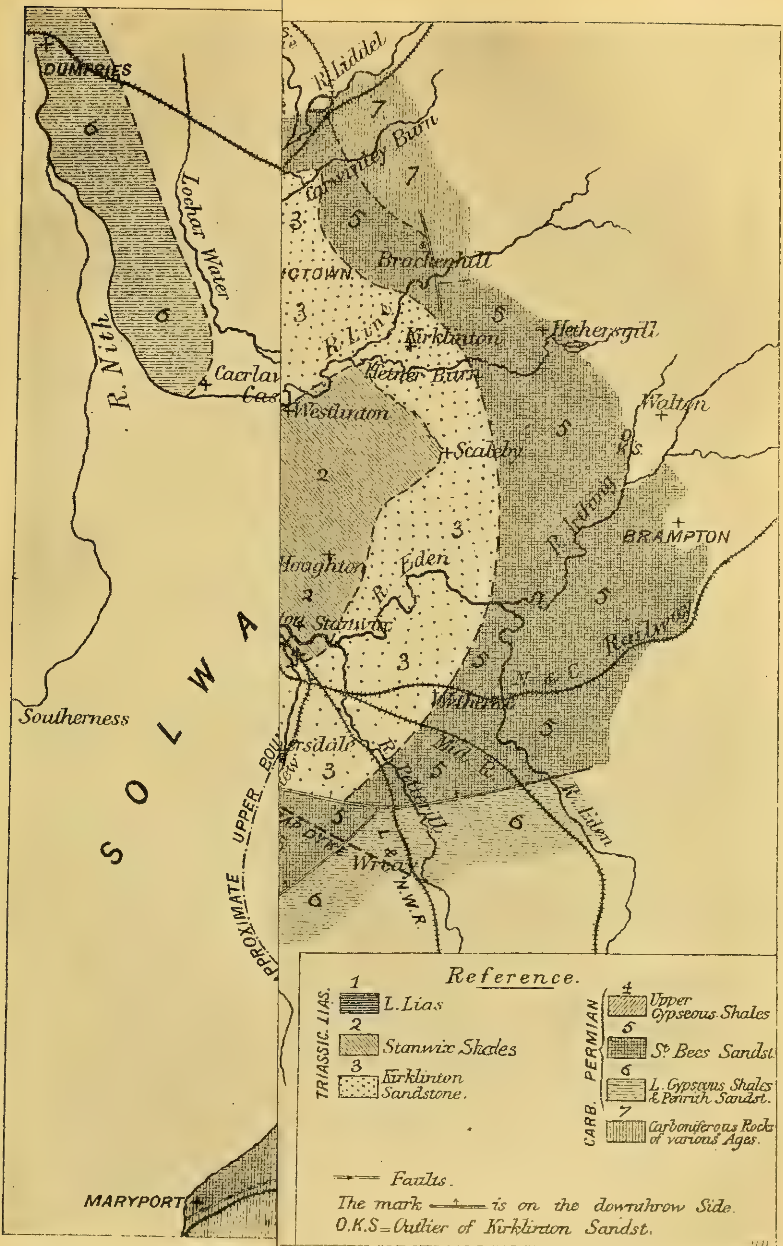
Then Professor Gregory is very doubtful as to the identification of the sandstone in the Abbey Town boring, beneath the Gypseous Shales, as the St. Bees Sandstone, and thinks it was in all probability Penrith Sandstone. He notes, in connexion with this view, that though I wrote on this district for the Geological Society in 1881 and for the Geologists' Association in 1889, my first mention of having seen the Abbey Town boring cores is in the Geological Survey Memoir of 1899. I was not aware of this omission till Professor Gregory noted it. But in the papers mentioned it did not occur to me to mention boring cores, simply because my knowledge of the geology of the district and, I may add, that of my colleagues, J. G. Goodchild, of the Eden Valley district, and R. Russell, of St. Bees and Whitehaven, made the existence of the St. Bees Sandstone somewhere beneath the surface at Abbey Town almost an absolute certainty. The boring originated in a local belief that coal would be met with there at a very moderate depth. Neither R. Russell nor I were consulted before the Gypseous Shales were pierced through, and then the appearance of sandstone, not coal, caused us to be asked to examine the cores showing the beds from a depth of 945 feet to 1,020 feet. We came to the conclusion that the lowest bed, 32 feet thick, was "St. Bees Sandstone of the ordinary type" (Mem., p. 20). It seems worth adding that we came to the conclusion that "the greystone of the Caldew river-cliff appears to be represented in the boring by the grey sandstone and shale directly overlying the red rock in which the boring ends". Also that this view is somewhat confirmed by the opinion of my colleague, J. G. Goodchild, then working in the Eden Valley district. "He (Goodchild) also thinks that the beds between Bracken How and this spot (Abbey Town) are higher than any he has seen in the St. Bees Sandstone of the Eden Valley district where the top beds are cut off by the great Pennine fault" (Geol. Surv. Mem., p. 20).

Bracken How is a house on the River Caldew. On descending this stream St. Bees Sandstone first becomes visible about 500 yards south of the house, and appears thence, at intervals, as far as the house itself (Mem., p. 18).

It may be well to state that any classification of mine, at any time, of these rocks as Permian, Triassic, Bunter, or Keuper has been simply to mark their *relative* positions locally; and that any changes of name have been simply in deference of the classifications of writers with a wider knowledge of Permo-Triassic districts. For though the Permo-Triassic rocks of Cheshire or the Vale of York are not likely to be identified with special formations in Nithsdale, the Vale of Eden, or the Carlisle Basin, yet a broad knowledge of the various localities must be the safest guide to such general classification as may be possible.

Professor Gregory notes that "the Dumfriesshire continuation of the St. Bees Sandstone rests unconformably on the Carboniferous without any Permian beds intervening". He then proceeds to speculate as to what lines of fault, etc., might have produced this state of things, which he seems to consider so strange and abnormal as to require some very special explanation. He has also misunderstood the nature of the difference between my view and that of some older geological surveyors as to the probable sequence of the formations of the Carlisle Basin. They (as already stated) thought that the Kirklinton Sandstone was an older formation than the Gypseous Shales resting on the St. Bees Sandstone in the Abbey Town boring. And that these Gypseous Shales probably belonged "to the same subdivision as the Stanwix Shales" (preface to Geol. Surv. Memoir). For then the Lias would rest conformably upon these representatives of the Keuper Marls in Cumberland. My own view was that the Gypseous Shales were older than the Kirklinton Sandstone. These differing views were simply with regard to the relative positions of the Gypseous Shales and Kirklinton Sandstone, and had no bearing on anything but the position of the overlying Lias. There were no doubts as to the truth of my views with regard to the position of the St. Bees Sandstone: that it rested on Carboniferous rocks of various ages (except above Wreay in the Eden Valley) and was the oldest of the Permo-Triassic formations of the Carlisle Basin.

While the persistent drift covering the country west of Carlisle made the relations of the Gypseous Shales and Kirklinton Sandstone to each other doubtful, the St. Bees Sandstone occupies an area in which rivers, streams, and quarries show a considerable number of sections, both north and south of the Solway. Hence the position of


DUMFRIES
Lochar Water
R. Nith
Caerlav
Southerness
SOLWA
APPROXIMATE UPPER BOU
MARYPORT
R. Liddel
Bracken Hill
Kirklinton
Hethersgill
Kirkl Burn
R. Lyne
Westlinton
Scaleby
Walton
O.K.S.
BRAMPTON
R. Irthing
Houghton
R. Eden
Stanwix
Railway
N. & C.
Wetheral
R. Petteril
L. & N.W.R.
Wreay
R. Eden
Reference.
TRIASSIC. LIAS.
1 L. Lias
2 Stanwix Shales
3 Kirklinton Sandstone.
CARB. PERMIAN
4 Upper Gypseous Shales
5 St. Bees Sandst.
6 L. Gypseous Shales & Penrith Sandst.
7 Carboniferous Rocks of various Ages.
Faults.
The mark is on the downthrow Side.
O.K.S. = Outlier of Kirklinton Sandst.

BASIN.

81.

SKETCH-MAP SHOWING THE ROCKS OF THE CARLISLE BASIN

(*Disregarding Superficial Beds.*)

Scale 1 2 3 4 Miles

Reproduced by permission from Quart. Journ. Geol. Soc. Vol. XXXVII. Pl. XI. 1881.

the St. Bees Sandstone immediately above Carboniferous rocks of various ages has given rise to no differences of opinion among geological surveyors. Nor have any of them felt that there was any need of a special explanation of the structure of the district involving the existence of hitherto unsuspected faults, etc. And in cases of this kind the Geological Survey, in its knowledge of local developments, irregularities, and local peculiarities of Permo-Triassic rocks, has necessarily a great advantage over any individual geologist.

Professor Gregory thinks that the absence of older Permo-Triassic rocks between the St. Bees Sandstone and Lower Carboniferous rocks in this district demands the arrangement of a series of faults, etc., to account for it. And that the presence of a thick bed of Gypseous Shales *above* the St. Bees Sandstone (as demonstrated by the Abbey Town boring) when there is one in the Eden Valley district *below* the St. Bees Sandstone, is so nearly incredible as to make it almost certain that the supposed St. Bees Sandstone in the boring was really the Penrith Sandstone. But I have already mentioned that R. Russell and I examined the cores of the lowest beds of the boring and found them to be St. Bees Sandstone. In fact, the surprise to us was simply to learn the great thickness of the Gypseous Shales above it. And recognizing the St. Bees Sandstone as the oldest bed of the Carlisle Basin, the absence of St. Bees Sandstone beneath the Gypseous Shales, and the presence there of Penrith Sandstone, would have seemed to us almost impossible; and certainly a state of things only to be explained by some arrangement of faults, etc., of which there was no visible evidence.

In short, the existence of the St. Bees Sandstone as the lowest bed around the Carlisle Basin, and as resting mainly on Carboniferous rocks, is unquestionable, and the absence of older Permo-Triassic beds there between it and Carboniferous formations is simply a local state of things to be recognized, not one to attempt to explain away as though it were necessarily an illusion.

Similarly, as regards the presence of Gypseous Shales both above and below the St. Bees Sandstone. There is no inherent probability in favour of either one or two. All the geologist has to do is to ascertain which way the evidence points, and to decide accordingly. In a district with Permo-Triassic areas like those near the Solway much more local irregularity must be expected than in the Vale of York or in Cheshire. Hence, at the Geological Society's discussion last year on the geology of the Solway district, after Professor Gregory's paper had been read, Dr. A. Strahan, the author of many Geological Survey memoirs, including one on the neighbourhood of Chester, showed no feeling of the impossibility of believing that the St. Bees Sandstone could lie upon Carboniferous beds, but stated that it "rested upon Carboniferous rocks along its margin both on the Scottish and on the English sides of the Border".

Then, as regards the presence here and there of Carboniferous inliers in the St. Bees Sandstone, they have long been known to exist at Hethersgill, in Shalk Beck, and in the Roebeck. Hence the presence of that at Red Kirk, mentioned by Professor Gregory, points to no new conclusion, though interesting as a detail.

In conclusion, I would remark that the most valuable addition to our knowledge of the geology of the Carlisle Basin made since 1881 is that of Mr. Lamplugh. I refer to his statement at the meeting of the Geological Society on April 29, 1914—which I have already mentioned—that deep borings in the north of the Isle of Man showed the existence there of 700 or 800 feet of Gypseous Shales resting upon St. Bees Sandstone. These deep borings very decidedly suggest the prolongation of the Carlisle Basin to the north of the Isle of Man. And they also tend to remove any scepticism as to the possibility of the existence of Gypseous Shales *above* the St. Bees Sandstone in Cumberland as well as below it.

VI.—The Ice Age in England.

By Dr. Nils Olof Holst (late of the Geological Survey of Sweden).

ENGLAND has only had one Glacial Period. G. W. Lamplugh pointed this out in 1906 before the British Association at York, and quite lately also in 1913 before the International Geological Congress in Canada.[1] No one has yet attempted to contradict it.

It is true that more than ten years ago, in the third edition of *The Great Ice Age*,[2] James Geikie put forward his theory that there were no fewer than six different glacial epochs. But of these the two last are only post-glacial climatic changes of minor importance, and may therefore be left out of consideration here. The remaining four have all, significantly enough, received foreign names: Scanian, Saxonian, Polandian, and Mecklenburgian, and are based very little on British but mainly on Swedish and German observations. None the less, they are of so much importance to the geology of Britain that a brief examination of them may not be out of place here.

As regards the oldest of these, derived from Scania, the southernmost part of Sweden, it may be said without the least hesitation that it depends on a complete misapprehension.

As is quite natural, when the Scandinavian inland ice first began to move to the south it advanced with considerably greater rapidity over the level Baltic Basin than it did over the mountainous highlands of Sweden. By the former road, therefore, it arrived more quickly in Southern Sweden, and here, still following the line of the Baltic Basin, there arose a direction of striæ markedly at variance with that which characterizes the main track of the inland ice during its principal phase. It is just on this fact that the Scanian glacial epoch was based. Meanwhile it has been shown that during its last stage no less than during its first the inland ice moved more readily in the Baltic Basin, and that consequently it continued to move there longer than on the mainland, maintaining the same divergence in the direction of its striæ as during the first stage, and finally that the last stage was *in full continuity* with the main phase.[3] The grounds for a Scanian epoch have thus been entirely cut away.

[1] G. W. Lamplugh, 1914. "The Interglacial Problem in the British Islands": C.R. Congr. Geol. Internat. Canada, 1913, pp. 427–34.

[2] London, 1894, pp. 608–12. Cf. Journ. Geol. Chicago, vol. 3, pp. 246–52.

[3] J. C. Moberg & N. O. Holst, 1899. *De sydskånska rullstensåsarnes vittnesbörd i frågan om istidens kontinuitet.* Lund.

In no circumstances, however, could there be any question of ascribing to the oldest striæ in Scania an earlier age than Cromerian. In this province there has now been found an analogue of the Cromer River, the so-called Alnarps River,[1] and there is not the least doubt that this is distinctly older than any of the Scanian moraines or striæ.

Geikie's fourth glacial epoch, Mecklenburgian, also called "Epoch of the great Baltic Glacier", in spite of its first German name may also be called Swedish in so far as its establishment was prompted by G. De Geer's paper "On the Second Extension of the Scandinavian Land-ice", published in 1884.[2] The maps of this extension drawn up by Geikie and De Geer are almost completely identical. Concerning this proposal of 1884, it may be enough to say that eventually, ten years later, De Geer so completely gave it up as to express the wish that his view of 1884 might be considered merely as a "working hypothesis" needed for that date.[3] He was forced to this admission by Ussing, who was able to show that the inland ice of Denmark had never such an extension as was given to it by De Geer.[4]

There remain Geikie's two purely German glacial epochs; but it seems right and fitting to let the Germans themselves reply for them.

At the International Geological Congress in Canada W. Wolff, who, as a Prussian geological surveyor and in particular a Quaternary geologist of many years experience, knows the North German Drift as well as anyone else, subjected the 'glaciations' of Northern Germany to a critical but, as it seems to me, a somewhat too favourable examination.[5]

There "may be question", he says, "of three such, but in no circumstances of four." The first great difficulty met with is that no geologist can even yet fix the extreme limit for more than the middle one—the greatest glaciation. As regards the first, this may be explained by the fact that its traces are completely covered by those of the second or middle glaciation; but this explanation cannot apply to the third or last glaciation, the southern limit of which is supposed to lie somewhere between the Baltic and the Elbe, or perhaps south of the Elbe, without anybody precisely knowing where it really is.

Wolff admits, as he is bound to do, that it is only the interglacial deposits which can be adduced as proof for the separate glaciations. But no such persistent deposit traceable over the whole or the greater part of North Germany has ever yet been proved. The interglacial deposits are more or less local or sporadic, but such as they are they appear in considerable numbers and constitute the most confused

[1] N. O. Holst, 1911. "Alnarpsfloden, en Svensk 'Cromerflod'": Sveriges geol. Undersök., ser. C, No. 237.

[2] Gerard De Geer, 1884. "Om den skandinaviska landisens andra utbredning": Geol. Fören. Stockholm Förh., Bd. 7, p. 436. Also, 1885, Zeitschr. Deutsch. Geol. Ges., Bd. 37, p. 177.

[3] Feb. 4, 1904. Geol. Fören. Stockholm Förh., Bd. 26, p. 92.

[4] N. V. Ussing, 1903–4. "Om Jyllands Hedesletter og Teorierne for deres Dannelse": Oversigt Danske Videnskab. Selsk. Förh., 1903, pp. 99–152. Résumé en français, pp. 153–65.

[5] W. Wolff, 1914. "Ueber Glazial und Interglazial in Norddeutschland": C.R. Congr. Geol. Internat. Canada, 1913, pp. 467–77.

mixture of salt- and fresh-water deposits, peat and beds of multifarious composition, deposits more or less covered by moraine or frequently covered only by sand, and so forth. And Wolff might have added that from time to time the various deposits now known to be either pre-glacial or locally post-glacial have been made to serve as good proofs of an interglacial epoch. This production of proof has undergone a continuous and regular development: year after year the old proofs once thought so satisfactory have been found wanting and cast aside to make room for newer and better ones.

As "the most certain of all the North German interglacial deposits" is at present regarded the *Paludina* bed, which in Berlin and its environs has been shown to lie between two moraines interpreted as having been deposited during the first and the second glaciations. But this has not always been the case. F. Wahnschaffe, for many years the leading interglacialist of North Germany, expressed himself as follows about the *Paludina* beds in 1893 [1]: "*Paludina diluviana* had its home in the North German lowlands, before the lower moraine was deposited there, since the large accumulations of shells of both adult and young individuals as well as the condition in which the shells were preserved left no doubt but that the molluscs in the *Paludina* beds of Berlin occurred *in situ* ('auf primärer Lagerstätte'). On the other hand, in the moraine it is a derived fossil, and then it was driven for ever ('dauernd') from its old home." Subsequently, in 1901, the same geologist transferred the *Paludina* bed from pre-glacial to interglacial deposits, with the absurd consequence that there were no longer any pre-glacial deposits in the whole of the North German lowlands. "The existence of pre-glacial formations," says Wahnschaffe, "is not yet proved, inasmuch as the fossiliferous deposits formerly regarded as pre-glacial are now referred to Interglacial I." [2] But, as is well known, this warmth-loving snail has now withdrawn itself to the lower Danube, to the neighbourhood of the Black Sea. Moreover, it occurs fossil in North Germany together with admittedly pre-glacial Mollusca, and in England it is admittedly pre-glacial, since it there occurs only in the older pre-glacial deposits: in the *Neritina* locality at Swanscombe as well as that at Clacton-on-Sea. Thus the appearance of the mollusc in England is quite clearly decisive for Wahnschaffe's earlier view, and the first two North German glaciations are changed to a single one. Moreover, Wolff himself in another connexion explains that the oldest glaciation is very problematic ("dem ältesten Glazial haftet viel Problematisches zu").

Finally, as regards the "younger interglacial formations", which should distinguish the second and third glaciations, Wolff points out as an indisputable fact that, in consequence of their manifold forms and their position on so many different horizons, they cannot be regarded as contemporaneous. They are usually covered only by sand and gravel, no bottom moraine has gone over them, etc. He

[1] F. Wahnschaffe, 1893. "Ergebnisse einer Tiefbohrung in Niederschönweide bei Berlin": Zeitschr. Deutsch. Geol. Ges., Bd. 45, pp. 292–3.

[2] F. Wahnschaffe, 1901. *Die Ursachen der Oberflächengestaltung des norddeutschen Flachlandes*, 2 Aufl., p. 239, Stuttgart.

therefore regards them as due to many different oscillations of the inland ice. That is as much as to say that it is quite incorrect to imagine here two different glacial epochs, and indeed not quite correct to speak of two different 'glaciations'.

What we have here before us is nothing else than *the first great melting stage of the inland ice.* The limit of this in space lies between the periphery of the glaciated region and the 'circumbaltic' terminal moraine which can be followed through the whole of North Germany far into Poland, and on the other side up through the east part of Holstein and Schleswig into Jutland, where it curves round to the west and finally for about 56° 30′ of longitude turns directly westward towards England, as though it would continue its course there.[1] In time this melting stage must be ascribed to a period of milder climate well known to archæologists as characterizing the Aurignacian and Solutrian stages, a view elaborated in a previous publication.[2]

This melting stage can also be observed in England, and to some extent its limits can be traced there too, but this will be better discussed on a subsequent page. The only point to be emphasized here is that the correspondence between England and North Germany is so complete that even the latter country has no better claim to more than one ice age. In Belgium there is no trace of more than one, and in Holland likewise was only one, there called 'die Haupteiszeit'. In the last-mentioned country, however, geologists are at present uncertain whether it should be ascribed to the 'Riss' or to the 'Mindel' period, on the supposition, that is, that there really was more than one period. But it would seem that the problem of nomenclature might well be postponed until it has been proved that there really was in Northern Europe anything corresponding to the Alpine epochs of Penck. Penck, indeed, has never committed himself to this view, but has, on the contrary, expressly explained that he "holds the view that the classification of the Alpine glacial deposits cannot be transferred to North Germany without further evidence".[3]

Before the attempt is made in the following pages to draw the limits of the Ice Age in England and to assign it to its proper position, it seems fitting to say something about the pre-glacial conditions, which may be regarded as having in all probability had some connexion with the appearance of the Ice Age.

[1] Ussing, op. cit., 1903, see map.

[2] N. O. Holst, 1913. "Le commencement et la fin de la période glaciaire": L'Anthropologie, tome 24, p. 377.

[3] 1912. C.R. Congr. Geol. Internat. Stockholm, 1910, p. 1076.

To correlate the phenomena of the Ice Age within this little Alpine district with those in the great glacial district of Northern Europe constitutes undoubtedly no easy problem, and we cannot blame Penck if he delays to express himself upon it. "The master is still in his workshop, and has not yet finished his work." No one can wish to urge him on with indecent haste, but it would certainly be most illuminating if he would let us see what he already has finished. For one thing it might put a check upon his pupils, so that they should not in their enthusiasm press too far, and further than he himself wishes.

K. A. von Zittel has remarked that between the typical mammalian fauna of the Pliocene age, as found in the Val d'Arno, in Auvergne, and in the Montpellier district, and that which characterizes the older Pleistocene, there is intercalated a passage fauna, which for the most part agrees with the latter, but contains besides the following five species, namely, *Elephas meridionalis*, *Rhinoceros etruscus*, *Ursus arvernensis*, and the two species of *Cervus*, *C. Sedgwicki* and *C. verticornis*. Among places where this passage fauna is to be found is mentioned especially the Cromer Forest Bed, but also the French localities Saint Prest, Chagny, and Durfort, as well as some Italian localities. Here, then, appears to be a new division of time, as is maintained also by W. Boyd Dawkins, when he characterizes the Cromer Forest Bed as the period "when the Mammalia were migrating from Northern Asia" (and he might have added "and from Northern Africa") "into Europe in the pre-glacial or early stage of the Pleistocene period".[1]

The immigration into Europe of this late Pliocene or older Pleistocene mammalian fauna corresponds, as Von Zittel remarks, to a similar migration from North into South America and from South into North America.

In particular reference to the immigrating European fauna, he remarks that it required "together with a more temperate climate" also "an abundant vegetation", which in its turn must have required an abundant rainfall. During the preceding Pliocene times conditions had been otherwise. Then "large freshwater lakes were absent", that is to say, the rainfall was then less abundant.[2] This finds confirmation also in England, where the land and freshwater molluscs of the Pliocene are not known from freshwater deposits, but from the marine deposits of the Crag in which they have been embedded.

If Von Zittel's limitation of Pliocene time be retained, it may be definitely stated that it was towards its close that Europe became subjected to pluvial conditions, inducing a richer vegetation, which attracted the large and small herbivorous mammals; and that they in their turn attracted the large and small carnivores, as well as man, who, in a certain sense, may be regarded as the largest carnivore, since he lived on all the other animals. Thus man's contemporaneous appearance in Europe receives its full explanation.

The question of man's first appearance at the beginning of the pluvial epoch receives further elucidation from the following facts.

The English Cromer River must not be considered as an isolated example. There was also in the South of Sweden a very large, approximately contemporaneous river, the so-called Alnarpsfloden, which ran down from East Prussia over the southernmost part of Sweden, and then up to the "Norwegian trough". The oldest and deepest river-deposits in the valleys of the Elbe and Weser also appear to be approximately contemporaneous. All these rivers

[1] W. Boyd Dawkins, 1903. "On the discovery of an Ossiferous Cavern of Pliocene Age at Doveholes, Buxton (Derbyshire)": Quart. Journ. Geol. Soc., vol. 59, pp. 105–32. See p. 122.

[2] K. A. von Zittel, 1895. *Grundzüge der Palaeontologie.* See pp. 946, 947, 944.

resemble one another in that they flowed when the whole of Northern Europe lay considerably higher than at present.[1]

As regards such comparatively small rivers as the Thames, the Frome, and the Avon, the period of their strongest erosion certainly seems to have been somewhat later (Abstr. Proc. Geol. Soc., 1915, No. 972, pp. 70–1; No. 974, p. 85). But this does not contradict the supposition that they may have begun their course somewhat earlier, perhaps indeed near to the period of the Cromer River.

Palæolithic implements are said, as is well known, to have been found in the deposits of the Cromer River. The finds that I have had the opportunity of examining seem, however, to have an Eolithic rather than a Palæolithic cast. True Palæolithic finds cannot, however, be said to be entirely unexpected, since if the human jaw from Mauer really is contemporaneous with the Mastodon fauna occurring there, then the deposits containing it are older than those of the Cromer River, and man might just as well have left traces of his existence in the later deposits as in the earlier one, provided that he appeared in England as early as he did on the Continent.

The cave-deposits bear the same witness as the river-deposits, but, being more accessible to investigation, they speak a clearer language. Cave-deposits were, as a rule, laid down by subterranean streams, which, however, as proved by fossils, did not begin to run before the close of Pliocene times. The caves, therefore, are Pleistocene. Dawkins has, it is true, described a cave of Pliocene age found at Doveholes in Derbyshire, and mentioned by him as "the only Pliocene cave yet discovered in Europe". But he himself states that the Pliocene animal remains were 'derived' ("conveyed from a higher level into it [the cavern] by water").[2] This cave, therefore, is younger than the bones preserved in it, and it too may very well be of Pleistocene age.

Kent's Cavern, the most thoroughly explored of the English bone-caves, obtained the first material for its oldest deposit—a breccia—from sand carried by a subterranean stream which flowed through it. In this breccia are found the oldest Palæolithic flint implements, the so-called Pre-Chellean, right down to the floor, and bones of the cave-bear are found only a couple of feet above the floor.[3] For the rest the breccia has up to the present only yielded the bones of the cave-lion and the fox, and these are only of sporadic occurrence.

Similar conditions are met with in Brixham Cave.[4] The lowest deposit, "the shingle bed," was, it is plain, likewise laid down by a subterranean stream. Certainly it is very poor both in flint implements and bones, but among the latter the bear is represented, and the underground brook cannot have begun to flow much before the entrance of the oldest Palæolithic mammalian fauna.

[1] Holst, op. cit., 1911, pp. 30–1, 61–2.

[2] W. Boyd Dawkins, op. cit., 1903, pp. 129 and 125.

[3] Sixteenth and concluding Report of the Committee appointed for the purpose of exploring Kent's Cavern, 1881. Rep. Brit. Assoc. for 1880, p. 68.

[4] J. Prestwich, 1874. "Report on the Exploration of Brixham Cave": Phil. Trans., vol. 163, p. 471.

In the Belgian caves the conditions are different in so far as man appears in them (with the exception of the Spy cave) at a distinctly later date, but they are similar as regards the oldest bone remains of the cave-lion and the cave-bear. In the lowest of the five layers in the Hastière cave, the cave-lion first appears as the oldest animal. The same condition obtained in the third cave at Goyet. Here the cave-bear is found immediately above the horizon with the cave-lion.

Many other bone-caves might be quoted in illustration, all leading to the same result; their first filling up, being in connexion with subterranean water arising from a more copious rainfall, was not older than, but probably just contemporaneous with, the immigration of a new Pleistocene mammalian fauna. As regards the cessation of the pluvial epoch, it may here be enough to mention that as a rule it terminated at the same time as the Ice Age, and therefore did not come to an end quite at the same time in the northern and southern regions. In the bone-caves it usually ceased with the uppermost stalagmite, "granular stalagmite," as is the case in Kent's Cavern.

Even more clearly than in Europe can the pluvial epoch be observed in Northern Africa from Egypt to Morocco. There a number of places on the borders of the desert region were inhabited during Palæolithic times by no inconsiderable population, but are now uninhabitable. The power and high civilization attained by Egypt in post-glacial times under the first pyramid-building dynasty is but the continuation of a long development strongly fostered by nature during the pre-dynastic glacial and pluvial epochs. It should perhaps be recalled here that the first Egyptian dynasty began to rule 5,230 (3315 B.C. + 1915 A.D.) years ago (according to E. Meyer) or 7,415 (5500 B.C. + 1915 A.D.) years ago (according to W. M. Flinders Petrie), while the close of the Ice Age in Southern Sweden, according to my calculation based upon archæological finds in the Swedish peat-bogs, may be regarded as having taken place about 7,000 years ago (at a maximum).[1]

A discussion of the very extensive question of the North African climate in Pleistocene times would, however, lead us too far, and I shall here confine myself to referring my readers to an archæological work by Professor L. Capitan and his colleagues, in which are to be found numerous elucidations of the changes of climate in Northern Africa from Palæolithic down to historic times,[2] as well as to a report on various cognate observations made by the Geological Survey of Egypt.[3]

[1] N. O. Holst, 1909. "Postglaciala tidsbestämningar": Sveriges Geol. Undersök., ser. C, No. 216.

[2] J. de Morgan, Capitan, & P. Boudy, April, 1910. "Étude sur les stations préhistoriques du Sud Tunisien": Rev. École Anthrop. Paris, tome 20.

[3] W. F. Hume, 1910. "Climatic Changes in Egypt during Post-Glacial Times": pp. 421–4 of Die Veränderungen des Klimas. Sep. publ. Congr. Geol. Internat., Stockholm.

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

NOTICES OF MEMOIRS.

Opalized Shells from New South Wales.

On some Molluscan Remains from the Opal Deposits (Upper Cretaceous) of New South Wales. By R. Bullen Newton, F.G.S. Proc. Malac. Soc. London, vol. xi, pt. iv, pp. 217–35, pl. vi, 1915.

THE famous opal deposits of New South Wales, first referred to in geological literature by M. W. Anderson in 1892 as of Upper Cretaceous age and the probable equivalent of the Desert Sandstone of Queensland, has yielded from time to time the remnants of an interesting fauna and flora in which original structures have been replaced by opaline matter of rich and varied coloration. Further writers on this subject include the names of J. B. Jaquet, G. de V. Gipps, R. Etheridge, jun., H. Woodward, Ralph Tate, G. Gürich, A. S. Woodward, and F. Chapman. Some new material from White Cliffs (N.S.W.) was recently obtained by Mr. Newton from a gem merchant in Sydney, during a visit last year to Australia to attend the meeting of the British Association, and he has made it the opportunity of preparing a small memoir upon the palæontology of the deposits with special reference to specimens in the British Museum (Geological and Mineral Departments) and in the private collection of the Rev. F. St. J. Thackeray, of Mapledurham. Including the new species described, the Pelecypoda now comprise seventeen forms or species, whereas only two species of Gastropoda and three Cephalopoda have as yet been recorded. The genus *Unio* is recognized for the first time from these beds, three new species being described, while two new species of *Cyrenopsis* are also added to the fauna. Associated with these and other freshwater Mollusca are certain marine forms belonging to *Fissilunula*, *Inoceramus*, *Euspira*, *Actinocamax*, etc., which indicate an estuarine origin for the deposits. Mingled with these are fossils of other groups such as *Araucarioxylon*, *Isocrinus*, *Ceratodus*, *Cimoliosaurus*, *Polyptychodon*, and Dinosaurian remains. The author points out an interesting resemblance which he has traced between this fauna and that characterizing the uppermost Cretaceous beds of Canada, particularly the Belly River Series of Alberta, which is also of estuarine character, the inference being that the Australian opalized deposits were probably laid down in similar late Cretaceous times.

REVIEWS.

I.—C. Schuchert. Revision of Paleozoic Stelleroidea, with special reference to North American Asteroidea. United States National Museum, Bulletin 88, 302 pp., 38 plates. 1915.

THIS book is not what Professor Schuchert intended when he first began the work, but it will be most useful for all that. The most original part is the description of the older Palæozoic starfishes of North America. The account of the later forms, of the ophiurids and their allies, and of the foreign material is mainly compilation, and that it is no more is due to change of circumstances since the work was begun. Still, an intelligent compilation may be valuable as a summary of our knowledge, and certainly it is a great convenience to have had the literature so thoroughly ransacked for us.

The rather barbarous name Stelleroidea, adopted from Gregory, is intended to comprise all those animals generally known as Asteroidea and Ophiuroidea, with a number of other forms evidently allied to them but apparently forming distinct lines of descent, and therefore not properly to be placed in either of those Classes. To cover the same conception Mr. W. K. Spencer has restricted the name Asterozoa, which originally had a still wider content.

We can trace within known geological time the broad lines of development that gave rise to the modern Ophiuroid type, but the other groups, it is clear, already coexisted in fairly definite forms at the earliest period from which we have any traces of Asterozoa at all. That period is the Middle Ordovician, but the abundance and diversity of starfish life then appearing make it quite clear that there must have been ancestors provided with skeletons capable of preservation. Before we can advance much further the fossils of those ancestors must be found. They will decide between several conflicting theories. Professor Schuchert is led by various considerations to regard his new genus *Hudsonaster* as the most primitive known form. Besides ambulacrals and adambulacrals this contains inframarginals, supramarginals, and a dorsal radial series, but it has no accessory plates. The structure is simple, that is obvious; but this simplicity may be the result of specialization from a less definitely constructed ancestor. Professor Schuchert, however, does not think so, but imagines an ancestor more simple still. It all sounds very logical, but one is left wondering what the creature did for a living. There is also a curious want of harmony with the facts of embryology as regards the terminals, and one can hardly believe that there was so striking a difference in this fundamental point between the earlier Asteroidea and their modern descendants. Even Professor Schuchert seems to have his doubts. I would also venture a doubt as to his comparison with Echinoidea; at any rate it is far from certain that "the ambulacrals" of Echinoidea are the "same ossicles as in Stelleroidea", or that the "interambulacrals = adambulacrals of Stelleroidea".

It is not possible here to enter into a critical examination of the systematic descriptions, but I must not leave to another the ungracious task of pointing out that the new species *Hudsonaster batheri* is based on the imprint of the apical face of *Tetraster wyville-thomsoni*. I told Professor Schuchert this many years ago when I sent him the squeeze for study, and my verdict is now endorsed by Mr. W. K. Spencer from his renewed examination of the original specimens.

Congratulations to Professor Schuchert on having at last got this laborious piece of work into the world.

F. A. Bather.

II.—Some Mineral Oil Regions.

1. Report on Petroleum in Papua. By Arthur Wade, D.Sc.—The author is to be congratulated on having brought to notice a part of the Empire in which the oil indications are certainly widespread, though it remains for actual drilling to test the real productiveness of the field. The oil indications are noted in a series of sandstones and mudstones of Middle Tertiary age, and are folded in a general north–south direction. These beds are partly overlain by a calcareous succession of Upper Tertiary age, which has east–west trend lines parallel to the coast. It appears probable that the east–west trend lines of Java extend into Papua, and in the latter country they begin to swing round into the north–south trend lines which the author describes; this inference appears to be confirmed by the inconstancy of the trend lines in certain areas.

The hypothesis that the minor crumpling of the anticlines is due to the falling in of the crests is interesting and important in its technical application to oil drilling, but it certainly demands more proof than has been given in the paper.

2. The Moorcroft Oil-field and the Big Muddy Dome, Wyoming. By V. H. Barnett. (Bull. 581 C, U.S. Geol. Surv.)—Both these areas are composed mainly of Cretaceous rocks, the Montana and Colorado groups being well developed. Doubtful Jurassic beds also occur, while in Big Muddy Dome, Tertiary sandstones and shales occur in small patches. The general lithology and structure are similar to those of neighbouring oil-fields along the eastern border of the Rocky Mountains, but the commercial prospects are distinctly poor. In the Moorcroft region, a poor oil-bearing sand is noted, but the structure is unfavourable for subterranean storage, whilst in Big Muddy Dome it is significant that the only horizon which the author claims may contain oil in the middle of the dome, i.e. the Wall Creek Sandstone, has nowhere along its outcrop been proved to contain any bituminous matter.

3. Oil- and Gas-fields in Wayne and McCreary Counties, Kentucky. By M. J. Munn. (Bull. 579, U.S. Geol. Surv.)—The structure of this region is that typical of Pennsylvanian oil-fields, consisting of gently undulating strata ranging in age from the Ordovician to the Carboniferous. The latter is represented by a good development of both the Pennsylvanian and Mississippian subdivisions with the usual unconformable relationship, the Mississippian consisting mainly of limestones and containing the oil-bearing strata. The Chattanooga Shale at the base of the Carboniferous is correlated with the Devonian, though the evidence is unsatisfactory. Below these shales is a marked break in the succession almost eliminating the whole of the Silurian, whilst the Ordovician are not exposed but are found in boreholes.

With regard to the distribution of the oil pools, it is remarkable that these appear to occur in the sides of the gentle synclinal sags. This peculiar distribution may be the result of unequal porosity in the oil-bearing bed, and also the result of gas pressure in a water-free horizon.

4. Oil and Gas in the Western Part of the Olympic Peninsula, State of Washington, U.S. By C. T. Lupton. (Bull. 581 B, U.S. Geol. Surv.)—The country examined is composed of a strongly folded suite of Cretaceous and Lower and Middle Tertiary rocks, almost wholly covered by Pleistocene deposits. The exposures are rare, being confined to sea-coast and rivers, and the country densely wooded. It is hardly surprising that the author's idea of the general stratigraphy and of the structure, after such a short visit, is hazy in the extreme, and the account degenerates into a painstaking but tedious catalogue of dips and strikes.

The fact that oil and gas certainly exist, and that this region lies in the same trend-line with the rich Californian field, indicates that the region is worthy of careful investigation.

5. Oil Shale of North-Western Colorado and North-Eastern Utah. By E. G. Woodruff and David T. Day. (Bull. 581 A, U.S. Geol. Surv.)—The oil-bearing shale forms a part of the Green River formation, and occurs as beds of variable thickness up to 80 feet and is of lenticular shape, the whole outcrop extending over 100 miles in length along a sinuous escarpment.

The authors' description of the shale proves that the latter differs materially from the usual oil shale of Scotland, in that the large proportion of the bituminous matter occurs as free oil impregnating the shale. It is very questionable whether the authors' claim that the results of their experimental retorting have a limit of error of merely 20 per cent is borne out by experience. Distillation with small experimental retorts never yields the same results as with modern commercial apparatus, and, merely by the introduction of steam into the distillation, the yield of oil can often be increased by 50 per cent.

Finally, the economic aspect of the problem is largely dependent on an important factor which the authors appear to have overlooked, i.e. the yield of ammonia, and it is a pity that more data on this important factor have not been given.

6. The supposed Oil-bearing Areas of South Australia. By Arthur Wade, D.Sc. (Bull. 4, Geol. Surv. S. Australia.)—The district examined forms the coastal regions near Spencer Gulf and Kangaroo Island. The country is floored by an interesting series of pre-Cambrian metamorphic rocks—with local patches of Cambrian and Permo-Carboniferous glacial beds, and a thin veneer of Tertiaries —not a very hopeful region for the oil prospector. The author proves that all the reported oil shows are based on misapprehensions, and a large portion of the paper is devoted to the disillusionment of the general public on certain deeply rooted fallacies regarding the occurrence of oil. For the rest the paper adds little to our knowledge of the general geology.

III.—Oligocene Mollusca from the Silex Beds of Florida.

Dr. W. H. DALL has recently issued an exhaustive treatise on the *Molluscan Fauna of the Orthaulax pugnax zone of the Oligocene of Tampa, Florida,* which forms Bulletin 90 of the United States

National Museum, 1915, published by the Smithsonian Institution. Near Ballast Point in the neighbourhood of Tampa Bay, Florida, occur certain limestones associated with clays, marls, and cherts, which are very fossiliferous. The calcareous structures have disappeared through solution, so that the fossils are mostly represented by siliceous cavities the characters of which can be reproduced by wax or gutta-percha impressions, but where silicification has been more complete the organisms are preserved as beautiful translucent objects in silica besides being sometimes of various shades of brown. A number of silicified corals, also, accompany the shells of these deposits, as well as Foraminifera represented by *Orbitolites floridanus* of Conrad, a form closely related to Lamarck's *O. complanata* of the European Eocene. The author furnishes his monograph with an interesting review of the literature of the subject, commencing with the earliest notice of the beds written by John H. Allen in 1846 (Amer. Journ. Sci., ser. II, vol. i, pp. 38–42), followed by references to the researches of Conrad, J. W. Bailey, Heilprin, Dall, T. L. Casey, G. C. Matson and F. C. Clapp, Bailey Willis, and T. W. Vaughan. From the occurrence of the characteristic fossil, *Orthaulax pugnax,* in the Oligocene beds of Panama, Antigua, Anguilla, etc., the author considers that the Silex Beds of Tampa may be correlated with the Oligocene deposits of the West Indian and Caribbean regions. It is recognized that 312 species and varieties of Mollusca are now known from this zone, of which more than ninety are described on the present occasion as new; they bear the estuarine facies, being made up of land and freshwater species as well as marine forms. The whole of this fauna is systematically described and figured, the text occupying 173 pages, while the twenty-six plates of illustrations form a handsome addition to the work. The monograph, like all previous writings of the author, has been prepared with great thought and detail, many remarks being offered on conchological nomenclature which cannot fail to be of the utmost service to all students of molluscan science.

IV.—Brief Notices.

1. Human Remains and Implements in England.—In a recent number of *L'Anthropologie* (vol. xxvi, p. 1, 1915) Professor Marcellin Boule has published a paper entitled "La Paléontologie Humaine en Angleterre". In this he gives a critical account of recent papers dealing (1) with flint implements and (2) with human remains. The first part is concerned chiefly with the vexed question of the nature of the so-called rostro-carinate implements from the base of the Crag. The author, after carefully considering the various papers dealing with the subject, comes to the conclusion that these implements are of purely physical and natural origin and not the work of man at all. The second part of the paper discusses for the most part the already large number of papers relating to the Piltdown man. Professor Boule on the whole supports the views of Dr. Smith Woodward as against those of Professor Keith. At the same time, however, he seems inclined to accept the very improbable suggestion put forward by

several writers that the mandibular ramus may belong to a different animal from the skull, and he objects to the use of the generic name *Eoanthropus*. The age of the deposits in which the remains were found is considered to be early Pleistocene.

2. In the Annals of the South African Museum (vol. xii, pt. ii, 1915) Mr. S. H. Haughton publishes several papers on South African Reptiles and Amphibia. The first describes a very fine skull of *Trematosaurus*, referred to a new species, *T. sobeyi*: the sutures are well shown in the specimen, and a detailed account of the various elements is given. The other papers deal with a new Dinocephalian similar to *Mormosaurus*, two new Therocephalians, and some new Anomodonts. The number of new genera and species of South African reptiles described lately is extraordinary, but since the material is often very badly preserved it seems probable that many of the names are really synonymous.

3. On an Extinct Marsupial from the Fort Union, with Notes on the Myrmecobidæ and other Families of this Group. By J. W. Gidley. (Proc. U.S. National Museum, vol. xlviii, p. 395, 1915.)—In this paper the author describes the occurrence in the Palæocene beds of Fort Union of a small Marsupial which he considers to be nearly related to *Myrmecobius*, hitherto the sole representative of a family found only in Australia. The new form, to which the name *Myrmecoboides montanensis* has been given, is, at present, known only from the ramus of a mandible, so that its affinities cannot perhaps be regarded as definitely settled, but the similarity of the dentition to that of *Myrmecobius* is very striking. If this relationship is confirmed the origin of some at least of the Marsupial families is carried much further back than was suspected, and it would appear that some of the Australian types were already differentiated before they became restricted to that continent.

4. Southern Rhodesia: Report of the Director, Geological Survey, for the year 1914. Fol.; pp. 8. 1915.—The Director (Mr. H. B. Maufe) explains that two new districts have been investigated during the period of 1914, which include the examination of the Kimberlite 'fissures' and 'pipes' in the Bembesi and Shangani basins and the mapping of the diamondiferous Somabula Series, together with the mapping of the Forest Sandstone and basalt country around Shiloh, situated to the north of Bulawayo. Reptilian remains were found when sinking a well in the Forest Sandstone at Waterfall Farm, which Mr. S. H. Haughton regards as belonging to a new species of Dinosaur whose nearest South African allies are of Upper Karroo age. It is therefore considered that the Forest Sandstone, which has hitherto not been satisfactorily placed in the geological series, should now be correlated with some member of the Upper Karroo System.

5. Geological Survey of Western Australia.—Bulletin No. 62 of this Survey, published 1914, contains "Notes on the Geology and Mining at Sandstone and Hancock's, East Murchison Goldfield", by E. de C. Clarke, with interpolated remarks on the 'Petrology' of the region by R. A. Farquharson. From a prefatory note of the

Government Geologist, Mr. A. Gibb Maitland, we gather that the most important structural and topographical features of Sandstone are the so-called 'jasper bars' which traverse the field in a general east and west direction. They pass imperceptibly into graphite schists below the ground, and from microscopical examination have evidently suffered intense shearing, being in places represented by chlorite-schists. Including the index, this work comprises sixty-six pages of text, maps, plans, etc., together with occasional micro-photographs exhibiting rock structures.

6.—Geological Survey of Ireland.

Explanatory Memoir to Sheet 58, illustrating parts of the Counties of Armagh, Fermanagh, and Monaghan. Second edition. By T. Hallissy; with Petrographic Notes by G. A. J. Cole. Department of Agriculture and Technical Instruction for Ireland, 1914. pp. i–iv, 1–26, with a coloured geological map, scale 10 miles to $3\frac{3}{4}$ inches. Price $3\frac{1}{2}d$.

The sedimentary rocks of this region are recognized as Ordovician (Lower Silurian), which include the Llandilo and Caradoc Beds; Gotlandian (Upper Silurian), Llandovery Beds; Carboniferous, embracing Lower Limestone, Calp or Middle Limestone, Upper Limestone, and Yoredale Series; Post-Pliocene and Recent, including Glacial Drift, Peat, and Alluvium. Ample notes are given on the palæontological facies of the Silurian and Carboniferous formations, the fossils from the latter having been determined by Dr. G. W. Lee and the late W. H. Baily. The mines and minerals of the district, as well as the soils and agriculture, form further sections of this report. Its extremely low price should commend this excellent work to all interested in Irish geology.

7. A Review of Mining Operations in the State of South Australia during the half-year ended December 31, 1914. No. 21. 8vo; pp. 35. Adelaide, 1915.

This is mainly of statistical interest to mining experts. There are, however, certain particulars given of boring operations which have been carried out at the Poona and Mattapara Mines, Moonta, by Mr. A. W. Matthews, and also at Calcookra Mine near Franklin Harbour by Mr. C. F. Duffield, which illustrate the rock structures of those districts. Mr. R. Lockhart Jack (Assistant Government Geologist) refers to the discovery of Alunite deposits on Section 310 at Hundred of Napperley, of which assays and analyses by W. S. Chapman are given. The Government Geologist, Mr. L. K. Ward, contributes a note on the cobalt deposits.

8. The Geology of the Appleby District. By Dr. John Edward Marr, M.A., F.R.S. With special reference to the area visited during the long excursion of 1907 by the London Geologists' Association. (Reprinted from the Proceedings of the Geologists' Association by permission of the Council of the Association.) Notes on the Geology of the Vale of Eden, by Professor P. F. Kendall. Appendix on the Igneous Rocks, by Alfred Harker. 8vo; pp. 27, with geological

maps and views. Appleby, 1915 (but not dated). Price 1*s.*—This work forms a useful guide to the geological structure of this district, and should be much sought after by tourists interested in the structure of rocks, the Appleby region being one of the best centres for such studies in Great Britain. Dr. Marr's portion of the work is a re-issue of his *Geology of the Appleby District*, published some years since, which, according to a newspaper paragraph, is now "brought up to date".

9. CATALOGUE OF THE BOOKS, MANUSCRIPTS, MAPS, AND DRAWINGS IN THE BRITISH MUSEUM (NATURAL HISTORY). Vol. V: SO–Z. 4to; pp. 1957–2403. London: Dulau & Co., 1915. Price £1 per volume.—We have already spoken (GEOL. MAG., 1903, pp. 415–18; 1910, pp. 475–6) of the merits and value of this Catalogue, and have therefore only to call attention to the completion of the main work. Mr. B. B. Woodward has fortunately catalogued the whole series from A to Z, and thus the publication has an uniformity and completeness unusual in so large an undertaking. While congratulating Mr. Woodward and expressing our indebtedness to him for the relief he has afforded to all those who struggle through scientific literature, we hope we shall not be indiscreet in mentioning that a supplementary volume which will include many additions and rarities acquired while the Catalogue has been going through the press (1903–15) has been arranged for. The manuscript for this is already nearly finished and will include the large and valuable library of entomological books and serials handed over by Lord Walsingham to the Museum with his collection of microlepidoptera. And advantage will be taken for the inclusion of bibliographic matter of any importance affecting the main entries, emendations of dates, and other detail for which we look in vain in most catalogues of the kind.

MISCELLANEOUS.

THE ROYAL SOCIETY OF CANADA, OTTAWA.—Mr. J. B. Tyrrell, M.A., M.Inst.M.M., F.R.S. (Canada), F.G.S., Mining Engineer, of Toronto, was elected President of the Geological Section of the Royal Society of Canada at its annual meeting held in Ottawa on May 25–7.

ERRATUM.—In the August Number, p. 353, footnote [1] (third line), for "deposited by the Rhine Glacier", read "Rhone Glacier".

THE following lines, indited by a friend after reading Matthew Arnold on Culture, have reached the Editor's box, and may serve to relieve the tedium of the season:—

CULTURE AND KULTUR.

While *Culture* in Britain induces
  Swifter progress to Sweetness and Light,
His *Kultur* the German seduces
  Towards Arrogance, Envy, and Spite.

T. V. H.

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CATALOGUE of the MESOZOIC PLANTS in the BRITISH MUSEUM (Natural History).

By A. C. SEWARD, M.A., F.R.S., F.G.S.

Part I: **The Wealden Flora.** Part I: THALLOPHYTA—PTERIDOPHYTA. pp. xxxviii, 179. 17 Woodcuts and 11 Plates. With Alphabetical Index, Explanations of the Plates, etc. 1894. 8vo. Cloth. 10*s*.

Part II: **The Wealden Flora.** Part II: GYMNOSPERMÆ. pp. viii, 259. 9 Woodcuts and 20 Plates. With Alphabetical Index, Explanations of the Plates, etc. 1895. 8vo. Cloth. 15*s*.

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Part IV: **The Jurassic Flora.** Part II: LIASSIC AND OOLITIC FLORAS OF ENGLAND (excluding the Inferior Oolite Plants of the Yorkshire Coast). pp. xv, 192. 20 Woodcuts and 13 Plates. With Alphabetical Index, Explanations of the Plates, etc. 1904. 8vo. Cloth. 10*s*.

By MARIE C. STOPES, D.Sc. (Lond.), Ph.D. (Munich), F.L.S.

Part V: **The Cretaceous Flora.** Part I: BIBLIOGRAPHY, ALGÆ, AND FUNGI. pp. 285. With 2 Plates and Illustrations in Text. 1913. 8vo. Cloth. 12*s*.

NOW READY. PART VI.

Catalogue of the Cretaceous Flora. Part II: LOWER GREENSAND (APTIAN) PLANTS OF BRITAIN. pp. xxxvi, 360. With 32 Plates and Text-figures. London, 1915. 8vo. Cloth. £1 1*s*.

British Antarctic ('Terra Nova') Expedition, 1910.

NATURAL HISTORY REPORT.

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OCTOBER, 1915.

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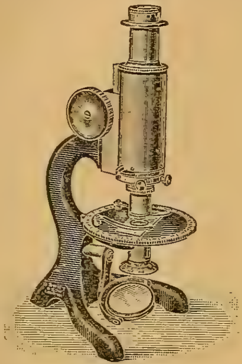

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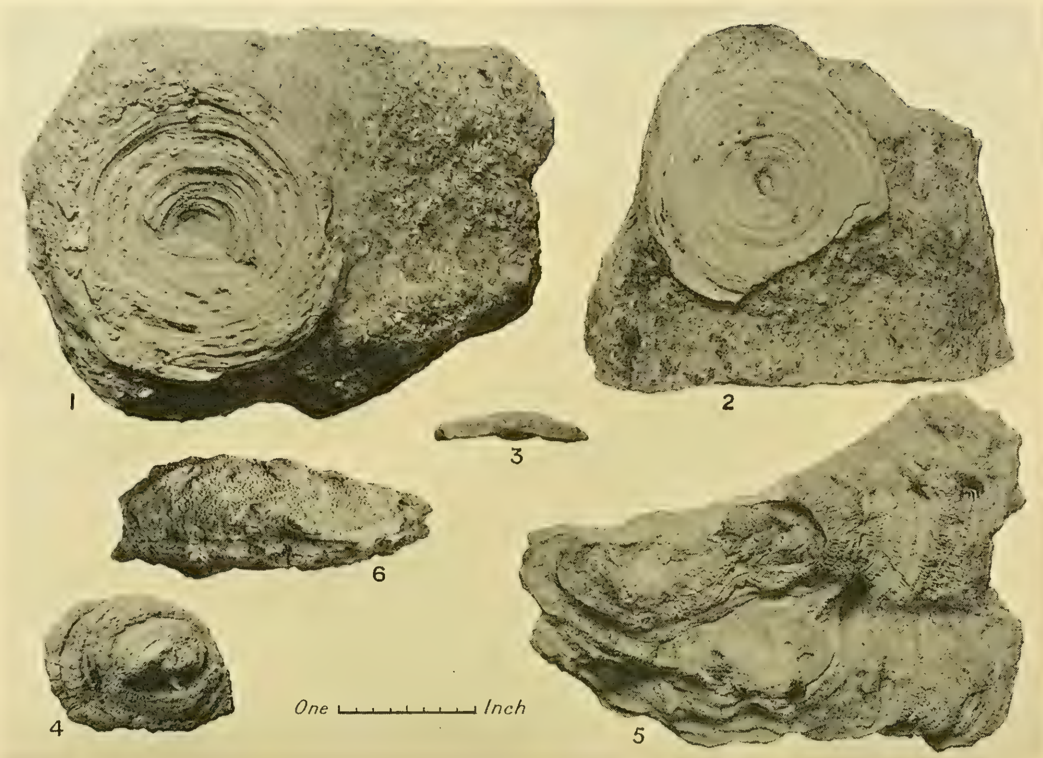

B

A.—Figs. 1, 2, 3. *Labechia rotunda*, sp. nov.—4, 5, 6. *L. conferta*, Lonsd.

B.—Type specimen of *Labechia rotunda*, sp. nov. (*nat. size.*)

(*To illustrate Miss M. S. Johnston's paper.*)

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. X.—OCTOBER, 1915.

ORIGINAL ARTICLES.

I.—On *Labechia rotunda*, a new species of Stromatoporoid, from the Wenlock Limestone of Shropshire.

By Miss M. S. Johnston.

(PLATE XV.)

WHILST working at the fossils connected with our paper "A Study of Ballstone and the Associated Beds in the Wenlock Limestone of Shropshire",[1] my colleague, Miss M. C. Crosfield, and I became much interested in a small round form of *Labechia*. We did not find many specimens, about a dozen in all, although we spent a considerable time in collecting, and these were obtained at only three quarries, which contain otherwise a prolific fauna, viz. Bradley Rock and Shadwell Rock, Much Wenlock, and at Knole Quarry, Presthope. The tops of these quarries are in the highest beds of the Wenlock Limestone series and are of bands of irregularly shaped nodules of various sizes, with shale partings and of a light-brown colour (this latter fact distinguishes the beds from the rest of the limestone). It is only in these upper beds that this *Labechia* is found, but *Labechia conferta*, Lonsd., is found, often in great numbers and size, everywhere throughout the limestone, though perhaps slightly diminishing in quantity at the top. So far, I have not been able satisfactorily to identify this species. Nicholson, in his monograph,[2] mentions and figures a young example of *L. conferta*, which he records as only being 2 to 3 cm. in diameter and 1 mm. in thickness. This specimen agrees with mine, but I cannot believe that they are young *Labechia conferta*, Lonsd., for several reasons—

1. The species is only found in the highest beds, never in the lower.
2. The largest I have is $5\frac{1}{2}$ cm. in diameter (Pl. XV, A, Fig. 1).
3. It is always thin, about 2 mm. thick (Pl. XV, A, Fig. 3, and B), and never has one colony superimposed on another (Pl. XV, A, Fig. 6; a *Labechia conferta* is 1 cm. thick).
4. The basal epitheca is nearly flat, not protuberant as is the case in many *L. conferta* (Pl. XV, Figs. 4, 5).
5. The rings of growth are always circular and never irregular (Pl. XV, A, Figs. 1, 2, and B).

The upper surface is seldom found exposed, but where it is seen it is irregularly or sometimes radially studded with minute tubercles.

[1] Proc. Geol. Assoc., vol. xxv, pt. iii, pp. 193–224, pls. xxxiii–vi, 1914.

[2] *British Stromatoporoids* (Pal. Soc.), p. 161, pl. iii, figs. 9–11.

They are not so high, but otherwise of the same size and shape, as the tubercles on *L. conferta*, and they also coalesce together. In the few specimens I have been able to examine, I have not found any summit-apertures on the tubercles. The rings of the base are ½ mm. wide. The radial pillars of the cænosteum, which have a diameter of ¼ mm., traverse each ring, in the direction of its width, before turning to the upper surface, and give the appearance of regular radial ridging.

It seems to be of rare occurrence, as through the kindness of Mr. H. Woods and Mr. H. A. Allen I have been able to ascertain that there were none in the Sedgwick Museum, Cambridge, nor in the Museum of Practical Geology, Jermyn Street. (I have been able to supply the latter.)

I am also much indebted to Mr. W. D. Lang, at the British Museum (Natural History), South Kensington, for the help he has given me. The specimen, figured by Nicholson, is at this Museum, but the place of origin stated, the Wren's Nest, Dudley, is doubtful. It is much more likely that it came from the Much Wenlock district, as also did the other small specimen in the Museum. For these reasons I would make this a new species with the name *Labechia rotunda*, taking as the type the specimen figured on Plate XV, B, which was found at Shadwell Rock, Much Wenlock, Shropshire, and which I have deposited in the Geological Department of the British Museum (Nat. Hist.).

II.—The Ice Age in England.

By Dr. Nils Olof Holst (late of the Geological Survey of Sweden).

(*Continued from the September Number, p. 424.*)

After the little survey of the pluvial epoch contained in the preceding section we may turn our attention again to England.

In the Thames Valley at Swanscombe (Barnfield pit) there is found beneath the deposits which yield early Chellean implements [1] a yet older layer which does not contain any implements.

Still somewhat younger, according to A. S. Kennard, is the so-called *Neritina* locality at Swanscombe. This, no less than the other, is of undoubted pre-Glacial age. Starting from this we may—thanks to the researches of the British palæontologists, and perhaps especially malacologists—construct a little series of other similar pre-Glacial occurrences in the following order from older to younger, all from the lower part of the Thames Valley.

1. *Swanscombe, Neritina locality.*—Characteristic molluscs: *Neritina grateloupiana, Valvata piscinalis*, var. *naticina*,[2] and *Vivipara* [*Paludina*] *diluviana*, which are all wanting in the following younger localities.

2. *Grays.*—*Valvata piscinalis*, var. *antiqua*. This is wanting in the following.

[1] *Elephas primigenius*, which is quoted as occurring in Barnfield pit, is really *E. antiquus*, the elephant characteristic of Chellean deposits.

[2] The statement that this mollusc is also found at Crayford depends upon an erroneous determination.

3. *Ilford.—Eulota* [*Helix*] *fruticum* and *Paludestrina* [*Hydrobia*] *marginata*, which latter is also found in 1 and 2. Both are wanting in the following.

4. *Erith–Crayford.—Corbicula fluminalis*, which is found also in 2 and 3, together with *Pisidium astartoides*, which is also found in 1, 2, and 3. Both are unknown from younger layers.[1]

These four pre-glacial occurrences are particularly interesting, since they show how one warmth-loving mollusc after the other disappears from the Thames Valley in proportion as the inland ice approaches; and the most warmth-loving as a rule disappears first. One of the earliest is *Vivipara* [*Paludina*] *diluviana*, which thus proves itself to be a distinctly pre-glacial shell, and even if found in a slightly later bed would still be pre-glacial. F. Wahnschaffe, therefore, as already remarked (p. 420), was completely right when, in 1893, he regarded this mollusc in the same way and called the *Paludina*-bed of Berlin pre-Glacial.

Of the four occurrences mentioned above, that of Erith–Crayford is the most interesting. It is the last in order and therefore that which came nearest to the Ice Age. None the less, it is certainly pre-glacial in this sense, that in England no earlier glacial epoch has ever been demonstrated or, we may be sure, ever will be demonstrated.

The molluscan fauna of Erith–Crayford, taken as a whole, is persistently temperate and pre-glacial, as is sufficiently proved by the presence of *Corbicula fluminalis*. *Planorbis arcticus*, however, has already come in, and *Pupa muscorum* has already become numerous.

At the same time, the more mobile mammals show more clearly than the two molluscs last mentioned that the inland ice is approaching. In the Crayford Bed are found *Ovibos moschatus*, *Lemmus* (two species), *Spermophilus* (here for the first time in England), *Microtus* [*Arvicola*] *ratticeps*, *Rhinoceros tichorhinus*, and *Elephas primigenius*, which is abundant, while *E. antiquus* has now become rare. *Hippopotamus*, which is already rare at Ilford and there perhaps only derived, has now wandered southward for good. It is the approaching inland ice which drives the northern animal before it.

Thus the mammalian fauna of Erith–Crayford shows precisely the same stage as the Campinian at Hofstade in Belgium. And I propose that this interesting and important stage should receive the name Campinian also in England.

The molluscan fauna, however, taken by itself, apart from the mammalian fauna, is quite enough to give the deposit of Erith–Crayford its true place, as appears from the following. My list of Mollusca from the Campinian of Hofstade is in large part new and not yet published, but when I showed this list to Mr. Kennard and asked him as to its English equivalent, he replied without the least hesitation, "That's Crayford."

Besides the molluscan and mammalian faunas, the Palæolithic finds also contribute to determine with certainty the correct period of Erith–Crayford. In the lower part of the Crayford Bed Mr. Brice Higgins—and others before him—has recently found Mousterian

[1] A. S. Kennard & B. B. Woodward, 1905. "The Extinct Postpliocene Non-marine Mollusca of the South of England": S.E. Nat., 1905, pp. 14–24.

implements.[1] Some of them can be completely matched among V. Commont's pre-Glacial implements from Moutières-les-Amiens,[2] as well as among M. de Puydt's contemporaneous implements from Sainte-Walburge.[3] In other words, it follows from this that the Palæolithic implements at Crayford belong to the oldest Mousterian, which has a stratigraphical position immediately below the deposits of the Ice Age, while the remaining portions of the Mousterian belong to the "maximum of glaciation".

Among the fossiliferous deposits at present known in the London district, the Arctic bed at Ponders End[4] belongs to the period immediately following the bed at Erith–Crayford. This both underlies and overlies gravel, and the whole is covered by loam. Since this last formation is the true 'late-glacial'[5] deposit, the Arctic bed cannot also be that. Neither can it be glacial. In that case it would have been deposited during some milder stage constituting a break in the Ice Age itself. For that, however, it is far too considerable, sometimes, as at Huxley Farm, attaining a thickness of several metres; besides, its flora and molluscan fauna are much too rich. It must then be *pre-glacial*, and, as such, is the latest known fossiliferous deposit in the Thames Valley.

The gravel *beneath* the Arctic bed is therefore itself also pre-glacial. The position of the upper gravel just below the 'late-glacial' loam indicates that it is glacial, and where the uppermost layers of the gravel yield huge blocks as they do at Hanwell, west of London, or where they are clearly contorted, there can be no doubt that the layers at any rate at these places were deposited during the Ice Age itself.

The *'late-glacial' loam*, which usually goes by the scarcely geological and frequently inappropriate name of 'brick-earth', belongs to the period of the melting of the inland ice. Here, however, we only have to deal with that part of the loam which during the first stage of the melting was deposited outside the true moraine region or

[1] R. Brice Higgins, Jan. 1914. "Flint Implements of Moustier type and associated Mammalian Remains from the Crayford Brick-earths"; with a note by R. A. Smith: Man, vol. 14, pp. 4–8.

[2] V. Commont, 1912. "Moustérien à faune chaude dans la vallée de la Somme à Moutières-les-Amiens": Congr. internat. Anthrop. Arch. préhist., Genève, p. 291.

[3] Marcel de Puydt, J. H. Nandrin, & J. Servain, 1913. "Le gisement de Sainte-Walburge dans le limon hesbayen": *Liége Paléolithique*, Liége.

Since this paper was written the author has visited the well-known locality Rickmansworth. At the bottom of the old river-gravel, 18–19 feet thick and only a few inches above the Chalk, are here found Chellean, Acheulian, and early, primitive Mousterian, all pre-glacial. This is therefore a new locality for "Mousterian with warm fauna".

[4] S. H. Warren, 1912. "On a Late Glacial Stage in the Valley of the River Lea, subsequent to the epoch of river-drift man": Quart. Journ. Geol. Soc., vol. 68, pp. 213–28.

[5] Here and in the following pages the usual term 'late-glacial' is used for the last glacial deposits in Southern England. This term, however, is correct only when applied *locally*, for if these deposits are considered in connexion with all the deposits of the Ice Age they cannot be described as really late-glacial, the true late-glacial deposits being much later. This question of terminology will be reverted to later on.

outside the periphery of the inland ice, and which, as will be shown later, must have been laid down in a large deep basin formed by the depression of Southern England. This depression was greater towards the north and the east, less towards the south and west, and may have reached as much as 200 feet below the present level.

This loam must therefore have had, and indeed still has, a wide distribution in Southern England, away from the northern boundary of Essex into the valley of the Thames, and along the southern coast right down to the Scilly Isles, where its presence has lately been proved by G. Barrow. We also find its equivalent in the large continuous loam tract in Belgium and in Northern France, of which more later on.

Concerning the loam in the Thames Valley, Mr. H. B. Woodward quite correctly says that this "appears to have been deposited for the most part in tranquil waters and has been described as an inundation-mud". It varies, he says, in thickness "from a few feet to 20 feet or more".[1] A characteristic of it is that it lies without any passage on the older gravel, also that it is not to any noteworthy extent washed out on the surface; whence it may be concluded that the water from the loam basin was emptied out with considerable rapidity, an important circumstance to which there will be occasion to refer later on. In one locality, Green Lane brickyard, at Acton, London, W., I have seen horizontal layers of sand and clay beautifully alternating through the lower part of the loam, here 12 feet thick, but often the fine clay goes right down to the bottom, to the gravel,

While the gravel in the last-mentioned brickyard, as Mr. F. Sadler kindly informs me, yields Chellean implements but never Mousterian, the loam, on the other hand, contains only late Mousterian implements, that is to say, precisely the type which belongs to the maximum of glaciation.

Exactly the same situation as the loam of the Thames Valley is occupied, just outside the moraine district, by the great tract of loam which in North-West Essex extends over the peninsula between the Rivers Stour and Colne.[2] Here too the lower beds may be sandy. The highest points of this clay tract lie between 161 and 187 feet, pointing to a corresponding depression during the deposition of the loam, or more correctly a somewhat greater depression, since the pure loam as a deep-water formation was never deposited on the shore-line itself. This seems to have been the greatest depression that affected Southern England during the stage in question.

On the southern coast of England there have been proved still *older* stages of depression than that during which the loam was deposited, but before considering these a few words may be devoted to the course of the depression taken as a whole.

The fact has already been recalled that England, like the whole of Northern Europe, during an earlier pre-glacial stage lay considerably

[1] H. B. Woodward, 1909. *The Geology of the London District* (Mem. Geol. Surv. England and Wales), see p. 74.

[2] See the Geological Survey drift maps and memoirs, to which reference may also be made for the following account of the Pleistocene deposits in Southern England.

higher than now. The Cromer River to the north, and the Hurd Deep River to the south, of the Straits of Dover are sufficient and clear proofs of this. Men and beasts had then no difficulty in wandering from the continent to England. But it is equally clear that when the former river disembogued to the east of the present coast of Norfolk a sinking of the land was begun. A later, more advanced stage of this sinking has been proved by some borings in the coast district of Belgium: at Ostend, at Leffinghe, south-west of Ostend, and at Petit Crocodile, north of Middelkerke. So long ago as 1884 Gustave F. Dollfus [1] drew attention to the Ostend boring, as indeed it well deserved. Briefly stated, at Ostend at a depth of 22·45–33·5 metres [2] below the surface, which lies only a few metres above the level of the sea, there has been found a rich marine fauna, which, however, is entirely devoid of southern species. From this Dollfus draws the obviously correct conclusion that the North Sea was not yet in connexion with the English Channel. The Straits of Dover did not then exist.

The same was the case at least at the beginning of that considerably later stage of depression to which the so-called 'raised beach' on the south coasts of England and Wales and on the French coast (at Selsey, at Brighton, on Gower, at Sangatte, etc.) bears witness. In the Selsey Beach, for instance, the lower layer yields a marine molluscan fauna with forms of so southern a character that they have now to be sought as far down as the coast of Portugal.[3] This 'raised beach' depression is clearly pre-glacial, while the succeeding depression may be called glacial, since it was during it that the glaciation reached the maximum, while it came to a close with the deposition of the 'late-glacial' loam.

It was during the succeeding *glacial* depression that the marine North Sea fauna, more like the present one, first came down to the south coast of England, where it is observed in the Chichester district, at Oving, and at Goodwood Park. The Straits of Dover are now open, and England is no longer connected by land with the continent. J. Prestwich, however, who came to the same conclusion as long ago as 1865,[4] though by quite a different road, has shown that they were open when the sand that covers the 'raised beach' at Sangatte was deposited; and in so far as this sand really belongs to the older stage, the opening of the Straits must have already been effected during its latter portion. This chronological discrepancy is not great, and entirely disappears if it can be shown that the North Sea fauna migrated to the south coast already during the last stage of the 'raised beach'. Here, nevertheless, we may recall the fact that R. A. C. Godwin-Austen observed "a black band", or, in other words, "an old terrestrial surface," between the pre-glacial 'raised

[1] G. F. Dollfus, 1884. "Le terrain quaternaire d'Ostende et le *Corbicula fluminalis*": Ann. Soc. malac. Belgique, tome 19, pp. 28–54.

[2] The depth in the other localities is less: 12·2–24·9 and 14·8–21·5 metres.

[3] R. Godwin-Austen, 1857. "On the Newer Tertiary Deposits of the Sussex Coast": Quart. Journ. Geol. Soc., vol. 13, pp. 40–72, see p. 54.

[4] J. Prestwich, 1865. "Additional Observations on the Raised Beach of Sangatte, etc.": Quart. Journ. Geol. Soc., vol. 21, pp. 440–2.

beach' at Sangatte and the superjacent layer which belongs to the glacial depression; this surface would imply at any rate a short break in the sinking of the land.[1]

A further interesting observation has been made by A. Bigot at Saint Aubin in Calvados.[2] At a height of 2 metres above high-water level he has found a beach deposit which contains among other marine molluscs *Buccinum grœnlandicum* and *Trophon antiquum*, that is to say, still more northerly species than those known from the south coast of England. Since this beach deposit is covered by the loam, beneath which in other localities Mousterian implements have been found, it indubitably belongs to the deposits of the glacial depression, and shows that the North Sea water which streamed in through the newly opened Straits of Dover straight against the French coast, just before the deposition of the 'late-glacial' loam, was very cold, and considerably colder than it was when the marine fauna of a slightly earlier period came to the south coast of England near Goodwood Park.

The deposits from the two stages of depression, the pre-glacial 'raised beach' stage and the glacial stage, claim further attention. Both have been exhaustively described by J. Prestwich.[3] On the Gower Peninsula in South Wales the 'raised beach' is stated to reach a height of 25 feet above O.D.,[4] at Brighton 24 feet,[5] at Sangatte 10–12 feet,[6] and at Menchecourt near Abbeville, where the ground lies about 15 metres above the sea, the corresponding marine beds, resting on deposits with Chellean implements, rise to 24 feet above O.D.[7]

Various observations on the 'raised beach' render it possible to determine the age of its formation with fair accuracy. The fact, made known by R. H. Tiddeman, that the 'raised beach' on the south coast of Wales is covered by moraine proves it to be distinctly pre-glacial. In two caverns, Bacon Hole and Mitchin Hole on the Gower Peninsula, are found various mammalian remains, and among them *Elephas antiquus* and *Rhinoceros leptorhinus*, both in the marine sand of the 'raised beach' and immediately above it.[4] These fossils indicate an age corresponding to that of Grays or Ilford, but distinctly older than that of Erith-Crayford. Acheulean finds in the middle of the 'raised beach' at Brighton show that the beach cannot be older than Acheulean,[5] but that stage was not of particularly long

[1] R. A. C. Godwin-Austen, 1866. "On the Kainozoic Formations of Belgium": Quart. Journ. Geol. Soc., vol. 22, pp. 228–54, see p. 253.

[2] A. Bigot, 1897. "Sur les dépôts pleistocènes et actuels du littoral de la basse Normandie": C.R. Acad. sci. Paris, tome 125, pp. 380–2.

[3] J. Prestwich, 1892. "The Raised Beach and 'Head' or Rubble-Drift of the South of England, etc.": Quart. Journ. Geol. Soc., vol. 48, pp. 263–343.

[4] A. Strahan *et alii*, 1907. Mem. Geol. Surv. England and Wales, Expl. Sheet 247, Swansea, see p. 118.

[5] Reginald A. Smith, 1915. "Prehistoric Problems in Geology": Proc. Geol. Assoc., vol. 26, pp. 1–20, see p. 3.

[6] J. Prestwich, 1851. "On the Drift at Sangatte Cliff near Calais": Quart. Journ. Geol. Soc., vol. 7, pp. 274–8, see p. 278.

[7] J. Prestwich, 1894. "On the Evidences of a Submergence of Western Europe, etc.": Phil. Trans., vol. 184, pp. 903–84, see p. 910.

The Chellean finds from the low-water beach at Havre belong, on the other hand, to an earlier period, namely, that of the elevation of the land. See Bull. Soc. amis sci. nat. Rouen, vol. 34, pp. 129–32, 1898.

duration and comes immediately before the Mousterian stage, which is in the main the equivalent of a later geological stage, namely, the maximum of glaciation. At Menchecourt the 'raised beach' layer rests, as just said, on Chellean, and must therefore belong either to a later stage of Chellean or to the Acheulean. Lastly, as regards the erratics in the 'beach', they certainly bear witness to floating spring ice or perhaps also to floating icebergs (most probably the inland ice had already invaded Scotland), that is to say, they bear witness to *advancing* cold, but in no way, as some have tried to maintain, to retreating cold. All these observations concerning the age of the 'raised beach' are therefore not contradictory to one another and can be brought into complete agreement.

We now proceed to a somewhat more detailed account of the deposits of the glacial depression, which are undeniably of much interest. They consist of shell-bearing marine sand, gravel, which on the geological map sometimes is called 'valley gravel', partly rounded in the usual way, partly but little rolled and 'angular' ('coombe rock,' 'rubble drift,' 'head'), the two kinds of gravel being sometimes mixed, as well as loam, which has no fossils except for the very rare land shells that have been washed down into it.

These deposits are found along the whole south coast of England wherever the shores were not too steep to prevent their deposition, and have also been proved on the French coast at Sangatte. They are particularly well developed in the district round Chichester, Sussex. The formerly depressed region is here spread out as a remarkably fine and level sea-platform, the northern limit of which proceeds right across the map of the district in an almost straight east and west direction and immediately strikes one as an evident shore-line. In Goodwood Park the marine limit appears to ascend to a height of 157 feet above O.D. The marine fauna, so far as it is as yet known from the fine section at the last-named locality, is a North Sea fauna "like that now living on the south coast of England", with *Cardium edule*, *Mytilus edulis*, *Tellina balthica*, *Trophon* sp., as well as a newly found lamellibranch from the bottom layer of the locality, 'tabular concretions,' a small example kindly determined for me as a species of *Modiola* by Mr. R. B. Newton of the British Museum. "At first sight," says Prestwich,[1] "these sands appear unfossiliferous, but a short search shows the presence of a number of minute and very friable shells from ¼ to ½ inch long, and which proved to be the young, apparently, of the common mussel. I also found a few full-grown specimens of this shell and of the common edible cockle; but they all fell to pieces when touched." This I believe to depend on the fact that the water here on the south coast of England, which had become more and more cold during the glacial depression, now at last during the Goodwood Park stage became altogether too cold and also altogether too fresh to permit of the molluscan fauna which lived in it attaining its full development.

As regards the gravel, Godwin-Austen has remarked that it occurs,

[1] J. Prestwich, 1859. "On the Westward Extension of the old Raised Beach of Brighton, etc.": Quart. Journn. Geol. Soc., vol. 15, pp. 215–21, see p. 219.

or at least may occur, as two distinct layers, an observation the correctness of which I am able to confirm from the gravel-pits in Portfield immediately east of Chichester. It is most natural to regard the lower bed as deposited during the depression of the district, and the upper bed during the elevation which immediately succeeded.

The loam, the uppermost and last deposit during the period of depression now in question, occurs at some distance below the uppermost shore-line, in consequence of the fact that, especially on an open coast, it could only be deposited in deep water. It has the usual aspect of the 'late-glacial' loam. In Bognor it is said to be as much as 14 feet thick.

On the south coast of England the loam cannot, to any considerable extent, have arisen from the inland ice, which lay at too great a distance, but had as a rule a less remote origin, namely, from the south coast itself.

The glacial deposits now in question have been traced by Mr. Clement Reid from the Chichester map-sheet westward over the map-sheets of Fareham, Southampton, Bournemouth, and Dorchester, where its upper limit descends to a somewhat lower level. In the area of the Torquay map-sheet it may be observed in the shore deposits at Hope's Nose, where, however, it only ascends to 48 feet above O.D.; and west of Brixham Harbour, between there and Churston Cove, Mr. W. A. E. Ussher has directed my attention to a small but well-developed sea-platform covered with loam and reaching a height of about 50 feet.

Cornwall with its steep shores has a deposit called 'head', which follows the coastline and must therefore be a shore deposit. Concerning this and other coast deposits of Cornwall, Mr. Clement Reid has the following, as it seems to me, well-grounded remarks: "The succession in these Pleistocene deposits corresponds so exactly with that found along the Sussex coast that we cannot refrain from thinking that the strata are of the same date. The 'head' of the Cornish coast seems to be equivalent to the 'Coombe rock' of the Sussex coast." [1]

West of Cornwall lie the Scilly Isles, and here too is found the 'late-glacial' unfossiliferous loam as a thin deposit, and G. Barrow has been able to establish the fact that it has precisely the same aspect as the loam on the coast of Brittany. Here it contains 'scratched stones', which show that it is "essentially a glacial deposit".[2]

Eastwards from Chichester the gravel and loam deposits are proved to occur at various places on the coast, such as Brighton and Eastbourne. I have myself seen the loam in the neighbourhood of Hastings, and Professor X. Stainier, of Ghent, who there accompanied me, remarked on the extraordinary resemblance to the Belgian 'limon hesbayen'. At Sangatte, Prestwich observed both gravel and loam,

[1] C. Reid & E. M. Reid, 1904. "On a probable Palæolithic Floor at Prah Sands (Cornwall)": Quart. Journ. Geol. Soc., vol. 60, pp. 106–12, see p. 110.
[2] G. Barrow, 1906. Mem. Geol. Surv. England and Wales, Expl. Sheets 357 and 360, "Isles of Scilly," see pp. 27–8.

the latter with land molluscs washed into it, covering the older 'raised beach' up to 80 feet above O.D., a figure which cannot be regarded as representing the limit of its extent.[1]

The circumstance that the coast deposits along the south coast of England lie at a much lower level westwards than they do eastwards at once renders it probable that the depression of the land during which they were laid down was greater on the Continent than in England, and this in fact receives further confirmation. Thus, in Northern France, according to J. Ladrière, the 'late-glacial' loam is found up to a height of 240 metres[2] (=787 feet). The loam, therefore, has a much wider distribution on the Continent than in England, and stretches from Hofstade in North Belgium down to Finisterre in the south, where it is found on the northern side of the peninsula, but is wanting on the island of Ouessant as well as on the south side of the peninsula east of this,[3] while it covers the Channel Islands, which were "completely submerged" during its deposition.[4] The basin in which this peculiar loam was laid down was therefore very large and in parts also very deep.

As already stated, the loam contains no fossils. If this basin had been filled with sea-water this would be quite impossible. Almost equally impossible would it be if it contained ordinary fresh water. There remains, therefore, no other possibility than that the water was glacial, coming from the inland ice and the tundras, that the basin was closed in the north by the inland ice itself and in the south by an elevation of the sea-floor from Finisterre north-westwards, an upward pressure which may be regarded as having balanced the downward pressure and lowering of the land which was effected by the inland ice both in England and on the Continent along and in front of its extreme limit. These contemporaneous changes of level in two opposite directions can be explained only in one way, namely, as the direct and indirect result of the pressure of the inland ice. The succeeding post-glacial changes of level also find their full explanation in the same pressure and in the removal of that pressure. Such an explanation has appeared to be the only one that can be applied to the interpretation of the glacial and post-glacial changes of level in Scandinavia, in parts both rapid and great and followed by distinct wave-motions of the surface. Here we need only recall the fact that the glacial strand-walls in Northern Sweden, nearest to the former centre of the inland ice, now lie as far up as 260 metres (=853 feet) above the level of the Baltic, and that this huge and rapid elevation took place in connexion with, and immediately after, the melting of the inland ice, that is to say, as a consequence of the sudden removal of the pressure of the ice. Beside these Scandinavian changes of level, the elevation of the continental sea-platform south of the

[1] J. Prestwich, op. cit., 1851, p. 275 (the section), and op. cit., 1865, p. 442.

[2] J. Ladrière, 1891. "Étude stratigraphique du terrain quaternaire du Nord de la France": Ann. Soc. géol. Nord, tome 18, pp. 205–75, see p. 212.

[3] C. Barrois, 1897. "Note sur l'extension du limon quaternaire en Bretagne": Ann. Soc. géol. Nord, tome 26, pp. 33–44, see p. 39.

[4] A. Collenette, 1893. "The Raised Beaches, Cliff and Rubble-heads of Guernsey": Trans. Guernsey Soc. Nat. Sci., 1892, pp. 219–35.

English Channel up to a height of some 500 feet, as here accepted, may be regarded as comparatively small.

The view here expressed lays no claim to novelty. In 1908 A. L. Rutot upheld the necessity of supposing a 'lac hesbayen' in which the 'limon hesbayen' or loam must have been deposited; he has moreover printed a sketch-map indicating the limits of the Hesbayan lake,[1] certainly quite unlike the limits of the glacial freshwater basin postulated above; and Rutot himself, as he told me, had his predecessors.

The deposition of the loam cannot have required a particularly long time. In England I have not succeeded in finding any place where the yearly deposit was clearly enough shown to be estimated. On the other hand, in Belgium and Northern France there are many places in which it has been possible to make such an estimate. There the thickness of the yearly deposit varies between 1 cm. and 4 cm., and there is only one locality in which I have found it less than 1 cm. Let us now apply to the deposit of loam in England the last-mentioned figure, which is the same as I have been accustomed to use in Sweden when attempting to make merely a rough estimate of the time of formation of the late-glacial clays in that country. If, further, we take the previously given figure of 20 feet (or 6 metres) as close upon the greatest thickness of the 'late-glacial' loam in the Thames valley, then we reach a result of only 600 years as the approximate period for the deposition of this loam.

Before leaving the deposits which belong to the glacial period of depression we may with a few words contribute to a clear comprehension of the angular gravel (the so-called 'coombe rock', 'rubble drift', or 'head'). The upper, most angular, gravel is regarded as in large part deposited when the 'late-glacial' basin was emptied. This must have been a somewhat rapid process. The loam, as previously remarked, has not been rehandled to any great extent. It is not sandy on the surface, and the gravel itself shows that it was not exposed to the work of the waves for any lengthy period. It may here be worth referring to Prestwich's remarks on the 80 feet of rubble and gravel at Sangatte, especially with reference to the upper 20 to 25 feet in which there is a "preponderance of angular flints". Following a similar opinion to that expressed by Roderick Murchison, he sums up his view concerning the deposit in question in this well-considered verdict:[2] "The action which led to the accumulation of this Drift was sudden, powerful, tumultuous, not of long continuance, and suddenly arrested." This is indeed "hitting the nail on the head" in very few words.

The 'creeping-soil' theory has, as is well known, been applied more than once to the interpretation of the angular gravel. But it is altogether out of the question thus to explain a piling up of from 20 to 25 feet or still more of such gravel. Besides, if nothing more was required for this formation than the winter cold of the Ice Age

[1] A. Rutot, 1908. "Les deux grandes provinces quaternaires de la France": Bull. Soc. préhist. France, 1908, p. 8.

[2] J. Prestwich, op. cit., 1851, p. 276.

and the melting action of its summer warmth, why should this gravel not be found over the whole of Southern England, instead of being confined to the glacial depression-districts of the south coast?

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

III.—Note on a Fore-paddle of *Metriorhynchus* from the Oxford Clay of Peterborough.

By Charles W. Andrews, D.Sc., F.R.S. (British Museum, Nat. Hist.).

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In the description of the skeleton of *Metriorhynchus* given in vol. ii of the Catalogue of the Marine Reptiles of the Oxford Clay, very little could be said about the fore-limb. The only parts then known were a number of humeri and, in one or two cases, some small disc-like bones which were regarded as the radius and ulna: the most complete fore-limb was figured on p. 172 of the volume quoted. In order in some degree to fill this gap a short account was given (tom. cit., Introduction, p. xiii) of an imperfect fore-paddle of a specimen of the closely related *Geosaurus gracilis* from the Solenhofen limestone. This beautiful skeleton, originally described by V. Ammon (*Geognostische Jahreshefte*, vol. xviii, p. 12), has recently been acquired by the British Museum, and a photograph of it is given as a frontispiece to vol. ii of the Catalogue of Oxford Clay Reptiles. The specimen is beautifully preserved, and is remarkable for showing the outline of the tail-fin and other traces of the soft parts. Unfortunately for the present purpose the fore-limb is represented only by impressions of the bones, and no trace of the humerus can be seen, but still a good idea of its short paddle-like structure is given: this is shown in figure 1.

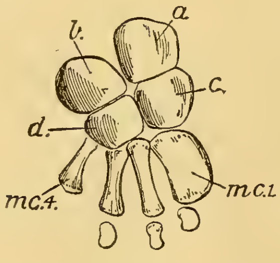


Fig. 1.—Fore-paddle of *Geosaurus gracilis*. *a*. radius; *b*. ulna; *c*. radiale; *d*. ulnare; *mc*. 1–4, metacarpals. R 3948. Nat. size. From *Catalogue of the Marine Reptiles of the Oxford Clay*, p. xiii.

It will be seen that proximally there are two pairs of disc-like bones, the homologies of which are not certain. Ammon regards the proximal pair (*a* and *b*) as being the radius and ulna, the distal pair (*c* and *d*) as the radiale and ulnare. Fraas in his account of the fore-limb of *Geosaurus* adopts the same view (*Palæontographica*, vol. xlix, 1902, p. 56, pl. viii, fig. 3), but in his specimens the bones of the proximal pair are much larger than the distal. If this interpretation is correct, then the distal carpals must have disappeared or, as seems unlikely, have fused with the proximals. The first metacarpal is an expanded plate, the other three rod-like; the fifth is wanting in Ammon's specimen, but is figured by Fraas, who also shows the number of phalanges as 2, 3, 4, 3, 2, but this is very uncertain; in *Geosaurus gracilis* Ammon figures a single phalange in each of the first three digits.

Recently Mr. A. N. Leeds has collected from the Oxford Clay of Peterborough a nearly complete left fore-limb of *Metriorhynchus*, together with portions of the right.

Fortunately the clay in which the left carpals and proximal ends of the phalanges lay has been preserved, and from the impressions of the bones their position can be determined. On the right side the second, third, and fourth metacarpals are in situ in the matrix, and there is an impression of the proximal end of the fifth. The humerus, radius, and ulna on both sides are unfortunately completely freed from matrix, and their exact relative position remains doubtful. Figure 2 shows what is regarded as the most probable arrangement of the bones of the left paddle (p. 446).

The *humerus* (*h.*) is much compressed from before backwards, and its preaxial border is produced into a strong deltoid crest, forming a triangular expansion and terminating in a small tuberosity. The head is oval and is strongly convex. Beneath the deltoid crest the shaft is a flattened oval in section, and the distal articulation is a slightly convex facet occupying the whole of the end of the bone and running up a little on to the preaxial border.

The *radius* (*a*) is a flattened plate the edge of which is thickened, and bears an articular facet on its upper inner border and another at its distal end. In front of these facets the body of the bone forms a large flattened expansion, projecting considerably preaxially. This bone is regarded as the radius (1) on account of its larger size, there being a tendency for the preaxial bones of a paddle to become enlarged, a condition here seen also in the radiale and first metacarpal; (2) because its distal articulation agrees very well with the upper articular surface of the radiale.

The bone here regarded as the *ulna* (*b*) is smaller than the radius. At its upper end it is much compressed and bears an oblique facet for the humerus; its posterior border is produced into a thin, sharp process, marked with striæ directed towards its apex—possibly this served for the attachment of a strong tendon. Distally the bone narrows and thickens, terminating in a rounded facet for the ulnare.

As already remarked, the exact relations of the radius and ulna to one another and to the neighbouring bones are uncertain, they being freed from the matrix, but in the case of the carpals and metacarpals the case is different, the bed of matrix in which they lay being preserved. The *radiale* (*c*) is the larger of the two carpals; its proximal border is thickened and bears a straight articular surface for the radius; its anterior border is convex, while the posterior is concave, and bears at its lower end a facet for the ulnare. Distally it articulated with the plate-like first metacarpal and perhaps partly supported the second.

The *ulnare* (*d*) is an oblong bone articulating with the ulna proximally and having a facet at the lower end of its anterior border for union with the radiale: distally it supported the third, fourth, and fifth metacarpals and to some extent the second.

The first metacarpal (*mc. I.*) is a thin, much expanded bone, probably triangular in outline when complete: it articulates with the convex border of the radius only. The second metacarpal, which is rather longer, is a narrow, compressed bone, expanding a little at its upper

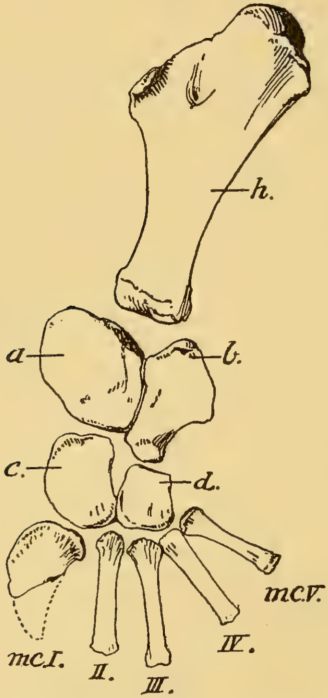


FIG. 2.—Left fore-paddle of *Metriorhynchus*. *a.* radius; *b.* ulna; *c.* radiale; *d.* ulnare; *h.* humerus; *mc.* I–V, metacarpals. Two-thirds nat. size.

end, which articulated between the radiale and ulnare. Distally it terminates in a sharp edge and probably had no phalange articulating with it. The third metacarpal is larger but otherwise similar: it articulates with the ulnare only. The fourth is about the same length as the second, but is considerably more slender. The fifth is about as long as the fourth, but has a more slender shaft. It has a marked expansion at each end, and distally bears a facet presumably for a phalange, the only one which appears to have been present.

The paddle of *Metriorhynchus*, as compared with that of *Geosaurus*, does not seem to have undergone such extreme modification especially in its proximal region: thus the humerus is still quite recognizably Crocodilian, while that of *Geosaurus*, figured by Fraas, is not. In the case of the radius, and more particularly the ulna, there are still traces of their condition as long bones, while in *Geosaurus* this is not the case. The carpals and metacarpal are similar in both genera, but the phalanges seem to have undergone most reduction in *Metriorhynchus*.

In most reptiles in which the fore-limb has become paddle-like it tends also to become larger, this enlargement being frequently accompanied by additions to the number of bones composing it. Thus, not only is it usual for the number of phalanges to be increased, sometimes very greatly, but additional elements may appear in the carpal region, e.g. in *Tricleidus*. In *Metriorhynchus*, on the other hand, the paddle-like modification was acquired while the limb was undergoing reduction, and in this case the number of elements has been much reduced, the phalanges having nearly, and the distal carpals entirely disappeared. The limb had already become so small that it can have been of little use in swimming or even in balancing.

Some dimensions (in millimetres) of this paddle are given below:—

Humerus: length		67
width of upper end		21
width at deltoid crest	(approx.)	27
width at distal end		15
Radius: greatest length		22
greatest width		26
Ulna: greatest length		26
greatest width		15
Radiale: greatest length		19
greatest width		15
Ulnare: greatest length		14
greatest width		12
Length of metacarpal I	(approx.)	19
II		23
III		26
IV		22
V		21

The two coracoids and the left scapula are also preserved, but they do not seem to differ in any marked respect from specimens described in the Catalogue.

IV.—Moine Pebbles in Torridonian Conglomerates.

By J. W. Gregory, D.Sc., F.R.S.

THE relation of the Torridon Sandstone to the Moine Gneiss or 'Eastern Schists' is one of the primary questions in the geology of the Scottish Highlands. These two widespread series of rocks occur on opposite sides of the great overthrusts in North-Western Scotland; and another remarkable feature of their distribution is that though the Torridon Sandstone often rests directly upon the Lewisian Gneiss, it never occurs on the Moine Gneiss. The view has therefore been suggested that the Moine rocks are the eastern metamorphosed continuation of the Torridonian. Some altered Torridon Sandstones certainly resemble the rocks of the Moine Series.

Dr. Horne,[1] in his address to the British Association in 1901, quoted the authority of Dr. Teall and Dr. Peach for the resemblance of altered Torridon Sandstone to the Moine; and he again remarked this resemblance in the memoir on the North-West Highlands.[2] The late W. Gunn went further, and in the same work claimed (p. 612) that "east of Dundonnell good evidence can be adduced that altered Torridon Sandstone has entered largely into the composition of the Eastern schists". The recent memoir on the Fannich Mountains represents some of the flaggy granulites of that district as due "to the crushing of Torridon Grit".[3]

As the Moine and Torridonian rocks both originated as quartzo-felspathic sediments, the fact that they give rise to similar rocks under the influence of dynamo-metamorphism does not prove that they are of the same age. The claim that the Moine rocks are altered Torridonian rests upon two main arguments. First, the absence of the Torridon Sandstone from the eastern side of the overthrusts, whereas, if it were a later formation, some outlier upon the Moine Series might be expected. The weight of this argument is lessened by the facts that between Loch Alsh and Glenelg typical representatives of the Moine Gneiss and of the Torridon Sandstone are faulted against one another, and that the Cambrian rocks also are absent from the surface of the Moine Series in the area east of the overthrust band.

The second and weightier argument rests on the view that no pebbles of the Moine rocks occur in the Torridon conglomerates; and if this fact were confirmed it would support the view that the Torridon Sandstone is not a later formation than the Moine. In the Survey Memoir on the North-Western Highlands, Dr. Teall's chapter on the petrography of the Torridon Sandstone contains an account of the included pebbles (op. cit., p. 283); he points out that schistose and highly metamorphic rocks are rare in the Torridonian conglomerates except in the basal breccias, which are full of Lewisian fragments. He mentions seven or eight pebbles from the Torridon Sandstone in the Survey collection, of which all but two or three are quite different from the Moine rocks; the others are "mainly composed of quartz showing marked signs of dynamic action", and these characteristics give no adequate clue to the origin of these pebbles. Hence the Survey memoir appears to support the absence of Moine rocks from the Torridonian conglomerates. So also does the more recent memoir on Sheet 92 (1913, p. 40), which gives a list of pebbles in the Torridonian beds, including "grit, quartzite, chert, jasper, felsite, and quartz porphyry, which are quite unknown in the Lewisian gneiss"; but it does not mention any rock that was regarded as even probably Moine.

[1] J. Horne, 1901. "Recent Advances in Scottish Geology": Rep. Brit. Assoc., 1901, p. 622.

[2] *The Geological Structure of the North-West Highlands of Scotland* (Mem. Geol. Surv. Great Britain, 1907), p. 468.

[3] *The Geology of the Fannich Mountains and the Country around Upper Loch Maree and Strath Broom* (Sheet 92, Mem. Geol. Surv. Scotland, 1913), p. 81.

On several occasions I have found pebbles in the Torridon Sandstone which appeared indistinguishable from the Moine rocks; and I recently collected several from a locality which affords an especially useful test. They were obtained on the northern shore of Little Loch Broom, a quarter of a mile west of Badralloch, from cliffs of the Applecross or middle division of the Torridon Sandstone. The conglomerates there contain many pebbles which exactly resemble the typical rocks of the Moine Series. Dr. Teall has kindly examined five of the specimens and slides cut from them; and he writes, "the three rocks (M 1, M 2, and M 5) are undoubtedly of Moine type, and the two quartzose rocks (M 3 and M 4) are like rocks associated with granulitic gneisses of the Moine group. I believe that all five rocks could be matched by rocks from areas mapped as Moine." The specimens have also been examined by Dr. Horne, who says, "there can be no doubt that they are typical siliceous granulites of Moine type." Mr. Tyrrell independently examined the slides, and he also says that three of the five specimens are typical granulitic Moine rocks; the other two, he remarks, are quartzites without distinctive features.

Dr. Horne remarked that it is possible such rocks might occur among the altered sediments of the Loch Maree type which are referred to the Lewisian.[1] This possibility seems remote. The nearest exposure of the Lewisian rocks is about $2\frac{1}{2}$ miles from Badralloch on the opposite side of Little Loch Broom, and in that district they are the normal type; and the altered sediments which are referred to the Lewisian are 15 miles to the south. The Moine rocks of Loch Broom are well exposed about five miles from Badralloch, though this proximity may be due in part to the overthrusting. The Moine rocks nearest Badralloch include both the granulitic micaceous gneiss and granulitic quartzite which occur as pebbles in the Torridon conglomerates. The quartzitic type has been described by Gunn (Geol. Surv. Memoir, 1907, p. 61), who says that in this district "there are also highly siliceous and massive kinds which approach the nature of quartzite, and contain little mica of any kind". These rocks are well exposed on the road south-east of Ullapool, near the head of Loch Broom.

The Torridonian pebbles of Little Loch Broom therefore differ from the local Lewisian rocks and are indistinguishable from the two typical rocks of the nearest outcrop of the Moine Series. Hence it appears more reasonable to regard these pebbles as derived from the similar local Moine rocks than to refer them to a hypothetical Lewisian source three times as far distant.

It may be urged that the presence of Moine pebbles in the Torridon Sandstone does not prove that all the Moine is pre-Torridonian; for the Moine may consist of two elements—(1) pre-Torridonian Moine rocks, from which these pebbles have been derived; and (2) Torridon Sandstone which has been altered into such Moine-like granulitic gneisses that they have been mapped by the Geological Survey as

[1] The Fannich memoir, Sheet 92, 1913, p. 9, remarks, however, that the relations of these altered sediments "to the members of the Fundamental Complex have not been definitely determined".

Moine. The suggested double age and origin of the Moine need not be discussed in this paper, the purpose of which is to show that the Torridon Sandstone does contain pebbles from the Moine.

The derivation of these pebbles from the Moine is consistent with the evidence of the felspathic constituents of the Torridon Sandstone. Dr. Teall remarked (North-West Highlands, 1907, p. 285) that the characteristic felspar of the red sandstones or arkoses in the Torridon Sandstone is microcline, which is not the typical felspar of the Lewisian, though it is often abundant in the Moine.

If the Torridon Sandstone includes pebbles of the Moine rocks, it must be a younger formation than the Moine Series.

V.—Polar Climates.

By R. M. Deeley, M.Inst.C.E., F.G.S.

PERHAPS one of the most unexpected facts concerning the geology of the Polar regions is the almost entire absence of pre-Quaternary rocks composed of glacial detritus, and the presence there mainly of sediments containing floras and faunas indicating warm climatic conditions. This is true of the rocks composing the Antarctic Continent as well as of the land masses in the neighbourhood of the Arctic Sea. Indeed, it is not until rocks of late Tertiary or Quaternary times are reached that we get any signs of continuous frigid conditions at the Poles.

However, there are rocks of several ages in many parts of the world which show that frigid conditions have existed in low latitudes, and even near the Equator itself, in pre-Quaternary times. Generally speaking, however improbable it may seem, the facts indicate that in pre-Quaternary times the world was warm or temperate throughout the greater portion of the time from the Equator to the Poles, but that there were occasional cold periods which affected areas in both high and low latitudes. In Quaternary times, however, the Polar regions were frigid throughout the whole interval, and have remained so; but there were also much colder intervals which affected all latitudes. Here we clearly have two phenomena resulting from different causes to deal with: the one an effect which caused occasional cold periods affecting the whole earth more or less, and the other a condition which, until recent times geologically, kept the Polar areas, like the rest of the earth, temperate or tropical in climate. Indeed, climatic zones would appear to be of comparatively recent development.

This almost complete absence of climatic zones in the past has been commented upon by F. Frech,[1] who points out that in 80° North latitude there prevailed in the past a temperate, indeed a warm temperate climate, for in Spitzbergen we have a fossil flora of evergreen growths and trees with acicular leaves similar to those of the Mississippi district, such as the swamp cypress. He contends that the climatic arrangement of the present day originated in a geologically recent time; but points to signs of the brief development of climatic

[1] Zeitschr. des Ges. für Erdkunde zu Berlin, 1902, pp. 611–29, 671–93.

zones at earlier periods of the earth's history. Eckhardt[1] also remarks that the geological contrasts up to the middle of the Cainozoic were not so pronounced as they are now, and it may be said with perfect safety that the climate of the Tertiary and the preceding geological epochs, especially in the Northern Hemisphere, had on wide stretches in the higher latitudes an apparently more insular character with less temperature extremes than the present, above all with warmer winters. Indeed, the late Tertiary earth movements seem to have resulted in a land distribution which caused a radical change in the climates of high latitudes.

The great uniformity of the forms of life flourishing at the same time in very different latitudes in past ages has greatly simplified the task of the correlation of widely separated rock formations, and what is often regarded as the mingling of boreal, temperate, and tropical forms of life in late Tertiary or Pliocene deposits, as at St. Erth, may be explained by regarding them all as warm temperate forms, the descendants of some of which have survived as temperate, some as tropical, and some as boreal forms, whilst some have become extinct. However, even before Red Crag times there were probably portions of the Arctic Sea cold enough to give rise to boreal forms of mollusca, etc., which spread south as the temperature fell.

With the causes that may have led at times to the lowering of the temperature of the whole earth I do not purpose to touch upon at all here. My desire is to call attention to certain considerations which may elucidate the difficulties that are met with in the study of Polar climates of past ages as shown by the geological record. Other hypotheses have been brought forward to account for the facts; but they have not received any general support and would take up too much space to fully discuss here.

It is agreed that at the present time ocean currents have a very powerful effect upon climate. They carry immense quantities of heat from hot to cooler regions, and warm regions are to some extent cooled by cold Polar currents. But although the heat is mainly carried from latitude to latitude by the water of the ocean, the direction in which the ocean currents travel is dependent upon the direction of the winds. If heat were not carried from latitude to latitude by ocean currents and the winds, the differences of temperature between localities in the same latitude but in different longitudes would be much less marked than they are. Such cold currents as flow from the Polar areas are caused to do so by the winds. If the surface winds travelled wholly towards the Poles the return colder currents would be deep-sea ones.

Labrador is in the same latitude as England, yet the climates are very different, and the difference is due to the fact that Western Europe enjoys south-westerly winds, especially in the winter, whilst Labrador is chilled by winds from the north. Bouvet Island and the Isle of Man are in practically the same latitude, yet the former is now glaciated down to the sea-level.

From the point of view of climate the direction in which the winds

[1] *Die Wissenschaft*, xxxi, Brunswick, 1909.

blow is of the utmost consequence. But it cannot be said that there is any general agreement among meteorologists as to the reasons why the general winds of the earth blow in the directions they do. If the flow were due to the temperature gradients as they now exist on the earth's surface, then the cold air at the Poles should flow towards the Equator as north-easterly winds in the Northern, and as south-easterly winds in the Southern Hemisphere, and there should be currents in the higher atmosphere moving towards the Poles. We should then have a belt of lowest pressure in Equatorial regions, and two high-pressure areas, one over the North Pole and another over the South Pole.

But the prevalent winds do not uniformly blow as above indicated. There is the low-pressure belt, and the winds as above described, in Equatorial regions; but instead of these winds coming from the Polar regions they come from two fairly continuous high-pressure belts at latitudes 30° north and south of the Equator.

In higher latitudes in the Northern Hemisphere the winds generally flow polewards as south-westerly winds at the earth's surface and north-westerly winds in the higher atmosphere. These are, of course, the general winds. In many continental areas, such as the Asiatic one, the change of temperature with change of season is very great, and we get such winds as the monsoons, which do not blow as do the trade winds or the prevalent winds of middle latitudes. In the Southern Hemisphere the north-west winds of middle latitudes blow much more regularly than do the south-west winds of the Northern Hemisphere.

Many theories have been propounded to account for these apparently anomalous winds of middle latitudes; but not one of these theories has received anything like general support, for they all fail in some respects to account for the facts. That a correct explanation of the circulation of the atmosphere should be found is most important from a climatological point of view, for such a theory may enable us to predict what effects would be produced if certain geographical changes occurred.

I have lately attempted to base a theory [1] upon the contentions of Halley and Hadley; but instead of considering the winds as blowing in accordance with the surface temperature gradients, they are regarded as being due to the horizontal temperature gradients of the whole thickness of the atmosphere. Recent soundings by registering balloons for ascertaining the temperature of the atmosphere have shown that the temperature of the upper atmosphere is greater in high latitudes than it is over the Equatorial regions. This is a very surprising fact, and if the temperature gradient of the upper atmosphere should be proved by further observation to be as great generally as the many hundred soundings already made show, then the upper temperature gradient should overpower the lower temperature gradient in middle latitudes and cause the lower winds of middle latitudes to move *towards* the Poles.

It is now recognized that the atmosphere may be divided into two

[1] *Phil. Mag.*, July, 1915, pp. 13–33.

distinct layers; a lower troposphere and an upper stratosphere. In the troposphere, as we ascend, the temperature falls at a rate which closely agrees with that of rising and adiabatically expanding moist air, i.e. *about* 0°·5 C. for each 100 metres of rise near the earth's surface. At Batavia,[1] about 7° south of the Equator, it falls somewhat irregularly until a height of 17 kilometres is reached, where the temperature has been found to be −89°·6 C. At 26 kilometres the temperature has risen to −57°·2 C. On the other hand, at Pavlovsk, near Petrograd,[2] in about latitude 59° 40′, the lowest temperature, the mean for the year, was reached at a height of 11 kilometres, and was only −53° C., rising to about −42 C., at 19 kilometres.

The following table shows the heights and temperatures at these two places:—

Height in km.	11	16	19	26
Batavia . . .	−45°	−86°·1	−78°·1	−57°·2
Pavlovsk . .	−53°	−48°·0	−42°·0	

We thus have opposing temperature gradients in the troposphere and stratosphere respectively. The upper side of the troposphere is that point where the temperature either only changes very slowly with increasing height or actually gets warmer as we rise. Its level is much higher in the Tropics than in Polar areas or middle latitudes, and is lower over low-pressure areas than over high-pressure areas. The upper layer is the stratosphere, and it rests upon the troposphere. The reason why the stratosphere in high latitudes has such a high temperature we need not here discuss.

Now if the lower atmosphere, or troposphere, should, from any cause, get warmer in Polar regions, then less opposition would be offered to the flow of the upper atmosphere towards the Equator, and the winds blowing towards the Poles from the high-pressure belts would be strengthened. Such warming of the troposphere in high latitudes would still further decrease the surface temperature adverse to winds blowing from the high-pressure belts at latitude 30° towards the Polar regions. There would thus be brought into operation a secondary effect which would powerfully assist still further to raise the temperature in high latitudes.

Warm seas in Polar regions would mean less cold conditions in the ocean and sea bottoms and would favour the existence of certain kinds of life at greater depths than that at which they now exist.

At the present time the South Polar area is occupied by a continent which is placed nearly concentrically with the Pole. The collection of snow and ice upon this land area keeps the troposphere temperature low, even in summer, and it here contends on fairly equal terms with the opposing temperature gradient in the stratosphere. Outside the Antarctic Continent, however, we have the seas warmed by the prevalent north-westerly winds. Over the sea, therefore, the temperature of the troposphere is less in conflict with that of

[1] W. van Bemmelen, *Nature*, March 5, 1914, p. 6.

[2] Gold, Meteorological Office Geophysical Memoir, No. 5, 1913 (M.O., No. 210*e*).

the stratosphere, and on this account the great cyclonic belt of middle latitudes is maintained.

In the Northern Hemisphere the geographical conditions are the reverse of those in the south. The North Polar area is a partially ice-covered water area, the temperature of which is never excessively low because the ice covering the sea is thin. The lowest temperatures occur over Siberia at Verkhoyansk. But this water-covered area is largely surrounded by land, and the warm ocean currents have only partial access to it. The surrounding land areas also result in the production of low winter temperatures, and the formation of one great cyclone such as that of the Southern Hemisphere is prevented by the irregular arrangement of the land and water areas. However, over the Pacific and Atlantic Oceans, where they approach the North Polar area, two cyclonic centres are formed which remain powerful in the winter. In the winter there are also high pressures over Asia, and south-westerly winds prevail between them and the North Atlantic depression. In the summer low pressures prevail over Asia, and the gradients for south-westerly winds over Europe are less steep.

The conditions existing in both hemispheres thus favour frigid Polar conditions. But the present arrangement of the land masses in the Northern Hemisphere is not such as existed in pre-Quaternary times. Many of the sedimentary rocks of Central North America, East Asia, and Mid-Europe are of ages ranging from Archæan to Miocene times. Bailey-Willis[1] has constructed a series of maps showing the areas in North America which were at various times probably land or sea. They all show that, in the past, what is now the area of the North American platform was more or less broken up into islands, large and small, and that there were very persistent and wide channels connecting the warm oceans with the Arctic Sea. According to Martonne[2] there was a channel connecting the Arctic Sea and the southern seas which passed over the area now occupied by the Ural Mountains, and which remained open during the whole of the Secondary and late Primary Eras. As far as the Northern Hemisphere is concerned it seems pretty clear that for long ages the openings from the south into the Arctic Sea were large and more numerous than they are now. At present our knowledge of the Southern Hemisphere conditions is less complete than is that concerning the Northern Hemisphere; but the flora and fauna of the Antarctic Continental rocks show that a large portion of them must have been below the sea-level at times, and that the climate must have been temperate. Indeed, the whole of the evidence we have points to the conclusion that in late Tertiary and post-Tertiary times the continental platforms became more land-covered than they had hitherto been; i.e. archipelagic conditions gave place in recent times to continental conditions.

Such an arrangement of the early land areas would of itself lead to warmer conditions in high latitudes, and this would reduce the strength of the temperature gradient in the troposphere. The stratosphere temperature gradient would then meet with less

[1] *Journal of Geology*, vol. xvii, 1909.
[2] *Traité de Géographie Physique*, 2nd ed., p. 595.

opposition, and the winds blowing towards the Poles would be increased in strength and produce a still further rise of temperature on the earth's surface in high latitudes.

The change from the archipelagic to continental conditions occurred about the time when, for some reason or other, the whole of the troposphere, and probably the stratosphere as well, became colder and the snow-line was lowered. Glaciers, consequently, formed on high mountain ranges and in high latitudes when the snowfall was sufficient. With the passing away of the conditions which gave rise to the Ice Age, glacial conditions disappeared almost entirely from all except high mountain ranges of middle latitudes; but owing to the joining up of the islands on the continental platforms frigid conditions remained over the Polar areas.

The whole subject of the climatic conditions through which the earth has passed is full of interest and difficulty. I have no wish to appear dogmatic on the subject, for much will have to be learned before any theory can be considered as probably correct. One thing seems to be pretty clear, and that is that until a sound theoretical reason can be given to account for the general winds of the earth blowing as they do there is little chance of dealing satisfactorily with the climatic changes which might result from geographical changes.

VI.—The Crawfordjohn Essexite and Associated Rocks.

By Alexander Scott, M.A., B.Sc.

Introduction.

Although the so-called Crawfordjohn essexite has been mentioned several times in petrographic literature, no detailed description of the occurrence has been given.[1] In 1888 Teall[2] described the main rock of the intrusion as an abnormal variety of the N.W.–S.E. Kainozoic dykes and noted the porphyritic augite and the abundance of felspar, olivine, and apatite. Lacroix,[3] in a general paper on the teschenites, mentioned the occurrence of nephelite in the same rock, which he described as an "olivine-teschenite, passing in structure to a tephrite". Bailey, in the Glasgow memoir,[4] remarked on the close similarity between the Crawfordjohn and Lennoxtown rocks and classed them with the essexites on account of their chemical similarity to the Brandberget rocks,[5] while Tyrrell,[6] on account of this similarity and also of the resemblance to the Carclout essexite, included them in the late Palæozoic alkaline group.

The intrusion occurs on the west side of Craighead Hill,[7] about one mile west of Abington Station and 2½ miles east of Crawfordjohn.

[1] No mention of it is made in the Explanation of Sheet 15 (Mem. Geol. Surv. Scotland), 1871.

[2] *British Petrography*, 1888, p. 197.

[3] *Compt. Rend.*, cxxx, p. 1273, 1900.

[4] *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, pp. 113, 130.

[5] W. C. Brögger, Quart. Journ. Geol. Soc., l, pp. 15–38, 1894.

[6] Geol. Mag. [5], IX, p. 121, 1912.

[7] The Craighead Hill, mentioned in *The Silurian Rocks of Britain* (Mem. Geol. Surv.), i, 1899, pp. 462–3, 501, lies in the Girvan Valley, Ayrshire.

The chief exposures are in Craighead Quarry, on the 1,000 ft. contour-line, and in a disused quarry 200 yards to the south-east. A number of isolated exposures are found further up on the hillside. The general trend of the exposures is a line running N.W. and S.E., which is apparently parallel to the northern contact with the sediments. The main rock is well exposed in both quarries, as is a fine-grained marginal facies, but although sediments are also seen the actual contact is usually obscured by drift or debris. The sediments, which are of Ordovician age, consist mainly of grits and shales, folded and lying almost vertical, and have undergone considerable metamorphism by the intrusion. The southern contact is nowhere exposed, but the grits occur in situ, in a small drift-covered quarry, 200 yards south of the large quarry. The main mass of the intrusion is a grey compact rock showing numerous phenocrysts of augite. In places, the porphyritic aspect is not so pronounced, and the rock is apparently more even-grained. As the edge of the intrusion is approached, the grain-size diminishes until at the margin the rock is thoroughly aphanitic, none of the minerals being distinguishable in the hand-specimen.

The Essexites.

Microscopically, the porphyritic rock is seen to consist of numerous crystals of olivine and euhedral lath-shaped felspars, accompanied by, and occasionally included in, large phenocrysts of augite. Ilmenite and apatite are fairly abundant, and sporadic flakes of biotite also occur. The interstices are filled with nephelite and analcite.

The olivine occurs in the usual rounded crystals and, as noted by Teall,[1] is generally fresh and distinctly greenish in colour. The crystals are often enclosed by the augite and are euhedral towards the felspar. They contain a number of minute inclusions of a greenish-brown colour. These have no cleavage, are distinctly pleochroic, the colour varying from greenish-yellow to light-brown, and have a maximum extinction of about 35°. The refractive index is high, and the double refraction fairly strong. These characteristics agree with those of orthite, and the presumption that the inclusions are composed of this mineral is strengthened by the appearance of a reddish alteration product and by the fact that a trace of cerium oxide (and possibly thoria as well) was detected during the chemical analysis of the rock. In some of the more altered rocks, the olivine is replaced by pseudomorphs which closely resemble those in the Derbyshire Toadstones described by Bemrose.[2] The alteration commences along the cracks, and the pseudomorphs, which have a good cleavage, appear to have the same optical orientation as the original crystals. The pleochroism is very intense, and the colour varies from a blue-green (when the light is vibrating parallel to the cleavage-trace) to a deep red. The refractive index lies between that of olivine and felspar, the double refraction is fairly high and the axial angle apparently large. Although similar pseudomorphs have been

[1] *British Petrography*, 1888, p. 197.

[2] H. H. Bemrose, Quart. Journ. Geol. Soc., l, pp. 603–42, 1894.

described from a number of localities,[1] in no case has the exact nature of the mineral been determined. It has generally been described as a mica or chlorite-like mineral. The optical properties resemble those of pennine, but the pleochroism is too intense and the double refraction too high for that mineral. The green colour of the olivine indicates a high content of fayalite, and it is probable that the pseudomorph is some type of iron-rich chlorite.

The olivine-crystals are often surrounded by an irregular border of strongly pleochroic mica, while sporadic flakes of the latter also occur throughout the groundmass. The mineral seems to have arisen through the resorption of the olivine by the water-rich residual magma which finally crystallized as analcite.

The augite occurs in large idiomorphic crystals, up to a centimetre in diameter, and has the purple colour characteristic of the so-called titanaugite of alkali-rich rocks. The crystals are often twinned on *a* (100), and irregular intergrowths and crystal-groups commonly occur. There are numerous inclusions of olivine, labradorite, apatite, and orthite (?), these being sometimes arranged parallel to the boundaries of the augite. Morphologically and optically, the mineral resembles the augite of the Bail Hill tuffs,[2] the hour-glass structure being very marked and a strongly-developed zonary banding being visible even in ordinary light. As determined in a number of twinned crystals, the extinction in the 'b-sector' of the hour-glass is 40° and in the 's-sector' 42½°. The mean refractive index is about 1·70 and the double refraction ·030, the optic axial angle, as determined by means of the Federov stage, being 57½°. The dispersion of the bisectrices is fairly high, so that sections in or near the symmetry-plane do not extinguish in white light. The pleochroism is relatively strong, the scheme being $\mathfrak{a}$ and $\mathfrak{c}$ yellowish-brown, $\mathfrak{b}$ reddish-purple (madder).

Some of the mineral was separated from the rock and analysed. This analysis, however, does not give the true composition of the mineral, as it is impossible to get rid of the numerous inclusions of olivine (sometimes occupying 20 per cent by volume of the augite). Column 6, table ii, gives the figures of the analysis made. It is certain that the ratio of lime to magnesia is too low on account of the amount of olivine present. The figures, however, could be used to determine the mode of the rock, as most of the inclusions are so small that they would be reckoned with the augite.

The plagioclase occurs as abundant lath-shaped crystals with the optical properties of 'basic' labradorite. These are sometimes sub-ophitically enclosed by the augite and occasionally even penetrate the olivine, but in general they are arranged in characteristic aggregates surrounding these two minerals. Occasionally much larger equi-dimensional crystals with well-developed zonal structure are found, and these appear to be of early formation. The orthoclase, which is

[1] H. W. Monckton, ibid., l, pp. 40–1, 1894; H. H. Bemrose, loc. cit.; J. S. Flett in *Geology of East Fife* (Mem. Geol. Surv.), 1902, p. 392; R. B. Young, Trans. Edin. Geol. Soc., viii, p. 327, 1903; S. H. Reynolds, Quart. Journ. Geol. Soc., lxiv, p. 508, 1908.

[2] A. Scott, *Min. Mag.*, xvii, pp. 100–10, 1914.

not abundant, also occurs in squat crystals, though sometimes it appears to border the plagioclase. The nephelite is fairly fresh and seldom idiomorphic, being usually found in irregular aggregates. The analcite is always interstitial and very fresh, and is distinguishable by its high relief and absence of double refraction. There are also numerous small eumorphic prisms of apatite. The iron-ore is apparently a titanomagnetite, and is generally surrounded by a narrow rim of deep-brown biotite.[1]

The olivine is invariably the first mineral to crystallize after the accessory apatite and orthite (?) and the felspar the second, since they both occur enclosed in the augite. In some cases, the felspar has begun to solidify while the olivine crystals were still growing. The last-formed minerals are nephelite and analcite, the latter of which has not only filled the interspaces but has also, while still liquid, corroded the already formed phenocrysts with the production of biotite. The formation of the latter mineral is therefore to be ascribed to the action of the water-rich magmatic residuum on the already formed olivine and magnetite.

Although the porphyritic rock is fairly uniform, local differences in the relative amounts and grain-size of the various minerals are common. Column 1, table i, gives the mineralogical proportions, as determined by the Rosiwal method, of a rock from one of the exposures on the hillside, while column 2 gives those of a rock from the large quarry. The ratio of augite to olivine varies considerably, the variation being quite irregular so far as position in the intrusion is concerned. While one specimen from the large quarry is very poor in analcite and nephelite, the total amount of these minerals being about 3 per cent, others, within a short distance, contain as

TABLE I.

	1.	2.	3.	4.	5.
Plagioclase, Orthoclase	32·2	30·9	35·2	23·3	32·3
Nephelite	7·1	4·6	15·0 [2]	12·6	6·1
Analcite	5·9	5·2		—	1·4
Titanaugite	27·4	41·0	34·5	36·1	25·9
Olivine	23·8	13·8	9·7	18·6	27·9
Biotite	·3	·4	1·5 [3]	3·6	1·4
Ilmenite	2·3	2·9	3·7	4·2	4·3
Apatite	1·0	1·2	·4	1·6	·7
	100·0	100·0	100·0	100·0	100·0

1. Essexite (normal type), Craighead.
2. Essexite (augite-rich type), Craighead.
3. Essexite, Carclout, Patna.[4]
4. Theralite, Lugar.[5]
5. Kylite (less femic type), Craigmark.[6]

[1] Cf. R. Campbell & A. G. Stenhouse, Trans. Edin. Geol. Soc., ix, p. 126, 1907.

[2] Includes some turbid unidentified matter.

[3] Includes a little hornblende.

[4] Cf. G. W. Tyrrell, Geol. Mag. [5], IX, p. 121, 1912. The writer is indebted to Mr. Tyrrell for the loan of slides of this rock.

[5] Ibid., p. 77.

[6] Ibid., p. 123.

much as 14 per cent. The distribution of the largest augites is also irregular, while it is curious that the very large crystals are often extraordinarily rich in inclusions. In the large quarry there are found several rocks which appear even-grained in the hand-specimen and some of which have pink felspar. In thin section, these are decidedly porphyritic, but the augite-phenocrysts are much smaller than in the rocks described above. The pink colour of the felspars is due to the fact that the latter are much 'analcitized', [1] being sometimes totally replaced by a dusty aggregate of analcite and other zeolites, although the interstitial analcite is often limpid and quite unaltered. In the neighbourhood of these rocks small clots, poor in ferromagnesian minerals but with abundant felspar and analcite, often occur.

TABLE II.

	1.	2.	3.	4.	5.	6.
SiO_2 .	44·37	45·03	43·65	43·10	40·87	43·94
TiO_2 .	2·37	2·30	4·00	2·80	2·85	4·38
Al_2O_3 .	14·19	14·82	11·48	13·94	16·23	7·01
Fe_2O_3 .	3·12	2·77	6·32	4·92	1·31	4·36
FeO .	7·28	8·71	8·00	6·93	7·37	9·68
MnO .	·24	·37	—	·14	·64	tr.
MgO .	7·84	7·79	7·92	8·86	9·83	10·81
CaO .	12·68	9·83	14·00	14·65	11·13	14·95
Na_2O .	3·86	4·33	2·28	2·50	2·78	3·76
K_2O . .	1·92	1·51	1·51	·89	·53	·57
H_2O + .	1·23	1·71 }	1·00	{ ·55	1·35	·04
H_2O − .	·24	·24 }		{ ·15	4·28	not found
P_2O_5 .	·83	·58	tr.	·27	·52	·41
CO_2 . .	not found	·22	—	·64	·38	not found
(Ba . Sr) O	tr.	—	—	·06	—	—
	100·17	100·21	100·16	100·40	100·07	99·91

1. Essexite, Craighead, analyst A. Scott.
2. Essexite, Lennoxtown, analyst W. Pollard.[2]
3. Essexite, Brandberget, analyst L. Schmelk.[3]
4. Essexite, Mt. Royal, Montreal, analyst B. J. Harrington.[4]
5. Theralite, Barshaw, analyst E. G. Radley.[5]
6. Augite (with inclusions), Craighead, analyst A. Scott.[6]

A sample of the fresh rock from one of the exposures on the hillside has been analysed and the results are given in column 1, table ii, several other analyses being included for comparison. The composition of the Craighead rock is very similar to that of the Lennoxtown essexite, and both resemble closely the Brandberget type. It was on account of this chemical resemblance that Bailey [7] classed the two former rocks as essexites. The name essexite was given

[1] Cf. J. S. Flett in *Geology of Edinburgh* (Mem. Geol. Surv.), 1910, p. 295.

[2] Summary of Progress of Geological Survey for 1907, 1908, p. 55; E. B. Bailey, loc. cit., p. 130.

[3] W. C. Brögger, loc. cit., p. 19.

[4] F. D. Adams, Geological Congress, Canada, 1913, Guide-book No. 3, p. 39.

[5] E. B. Bailey, loc. cit., p. 134.

[6] Another analysis of more impure material is given by G. W. Tyrrell, GEOL. MAG. [6], II, p. 363, 1915.

[7] Loc. cit.

by Sears[1] to an olivine-free soda-gabbro from Essex Co., Mass. Rosenbusch[2] expanded the term to include olivine-bearing types of the same rock, and also applied it to the Norwegian rocks which Brögger[3] had termed 'olivine-gabbro-diabase'. Owing to the fact that the amount of nephelite may vary widely, while olivine and hornblende may be absent or may be prominent constituents, the term essexite has been very loosely used, and rocks ranging from gabbro to theralite have been included in this class. The name should be restricted to those gabbroid rocks in which the felspar is strongly sodic and the nephelite small in amount. Where nephelite (or analcite) is a prominent constituent, the rocks should be classed as theralites, while the name essexite-theralite could be used for intermediate types. Where olivine or hornblende is present in notable amount, the terms 'olivine-essexite' and 'hornblende-essexite' could be used. Thus some of the specimens from Craighead could be included under the former name, while the latter could be applied to the dominant type in the Monteregian hills.[4]

That the Craighead rock is related chemically to the theralites may be seen by a comparison of columns 1 and 5, table ii, while the mineralogical connexion is evident from a consideration of columns 1 and 4, table i. This type, therefore, might be fitly termed an essexite-theralite, and the rock generally may be said to vary from a normal essexite to an olivine-essexite and essexite-theralite. Some of the olivine-rich varieties have obvious affinities with the less femic types of kylite (cf. column 5, table i), and it is apparent that by an increase in the amount of olivine a continuous sequence may be traced from essexite through olivine-essexite to kylite and finally kylite-picrite.

The Marginal Rocks.

Although several types of aphanitic rock can be recognized under the microscope, these generally exhibit a monchiquitic habit. One type, which occurs in the large quarry and may be distinguished in the hand-specimen by the 'spotted' appearance of the weathered surface, is rather less aphanitic than the others. In thin section it is seen to consist of abundant microphenocrysts of olivine and augite with scarcer felspar in a fine-grained matrix. The augite, though a titaniferous variety, is somewhat less pleochroic than the mineral of the essexites, while the olivine is usually replaced by an aggregate of fibrous serpentine. The ferromagnesian minerals are often poecilitically enclosed in the labradorite, a structure strikingly in contrast to that of the essexites, where augite is the enclosing mineral. The matrix consists of small granules of augite and magnetite in a dusty base of analcite and nephelite with locally a number of small felspar laths. Mineralogically the rock might be termed a nephelite or analcite basalt, but on account of its association

[1] Bull. Essex Inst., xxiii, p. 146, 1891.
[2] *Mikroskopische Physiographie*, 4th ed., 1908, II, i, p. 404.
[3] Loc. cit.
[4] F. D. Adams, loc. cit.; also *Journ. Geol.*, xi, pp. 239–82, 1903; J. A. Dresser, Geol. Surv. Canada, Mem. No. 7, pp. 14–18, 1910; J. J. O'Neill, ibid., Mem. No. 43, pp. 28–84, 1914, etc.

with the essexites and its intermediate texture, it may be included in the essexite-monchiquites. Lacroix[1] has applied this term to those monchiquites in which felspar predominates over nephelite and which have, in addition, an isotropic (presumably analcitic) groundmass. The Madagascar rocks differ from the one under consideration only in the presence of barkevikite and in a greater scarcity of olivine. The name is appropriate in the case of the Craighead rock, since, by an increase in the grain-size of the minerals, a gradual passage may be traced to a normal essexite.

Another 'spotted' rock represents a more felspathic and finer-grained type than the one described above. The phenocrysts are not so abundant, and the olivine rivals the augite in size. As before, both these minerals are poecilitically enclosed in felspar, which, however, also occurs as laths, of varying dimensions and often arranged in a radial fashion. The phenocrysts, together with a second generation of augite and numerous prisms of apatite, are enclosed in a matrix which is mainly analcite. In both of these rocks, local patches of a more acid nature occur. Olivine and porphyritic augite are absent, and the 'clots' consist of phenocrysts of labradorite in a groundmass of analcite, with subordinate nephelite and granular augite. These seem to be of late formation and to arise through the crystallization of a residual magma rich in water and alkalis.

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

VII.—On a New Genus and Species of the Thecidiinæ (Brachiopoda).

By J. Allan Thomson, M.A., D.Sc., F.G.S.

The subfamilies Thecidiinæ, Dall, and Leptodinæ, Schuchert, constitute the family Thecidiidæ, Gray, which is regarded by Schuchert as a near relation of the Strophomenidæ. The chief external characters of the Thecidiinæ are the smallness of the shells, the absence of the foramen, attachment by the ventral valve, the presence of a nearly straight hinge-line and of a prominent area with a solid deltidium. The shell substance, with the exception of the deltidium, is punctate. Internally the ventral valve bears in its hollow beak a small median septum on which is sometimes superposed a small muscular plate. The dorsal valve bears a so-called cardinal process, formed by the median union of the socket ridges, and this plate is strong, subrectangular, and hollow at its base, and projects beyond the hinge. In most of the genera two lateral spurs unite mesially to form a bridge just in front of the cardinal process, over the visceral cavity. There are no free brachial arms, but the brachial supports are represented by an anterior septum, frequently branched, and lamellæ rising from the floor of the valve in the spaces between the septum and its branches, the margins, and the bridge. The septum runs back from the anterior margin towards the bridge, and like the margins and the bridge, is more or less covered with granulations.

[1] *Nouvelles Archives du Museum* [4], i, p. 142, 1903.

The subfamily appeared in the Devonian,[1] attained its maximum development in the Jurassic and Cretaceous, and is still represented by three living species. The genera are founded mainly on the form of the septum. This is simple in *Davidsonella* and *Thecidella*, bears two lateral branches in *Lacazella*, and four lateral branches in *Thecidea* and *Thecidiopsis*. In *Thecidiopsis*, *Eudesella*, and *Pterophloios* there are in addition a number of lateral septa.

As in the case of the Terebratulidæ and Rhynchonellidæ, the type genus *Thecidea*[2] is often used in a broad sense practically synonymous with the subfamily. All the recent and Tertiary species have been ascribed either to *Thecidea* (*sensu lato*) or to *Lacazella*. There is, however, as Hedley has recognized,[3] a stock quite distinct from *Lacazella* which has not yet been named, and for this I now propose:

THECIDELLINA, gen. nov.

Genotype *Thecidium Barretti*, Davidson.

Shell subtrigonal, attached by the back of the beak; surface smooth or with concentric growth-lines. Hinge-line broad and nearly straight. Ventral valve with a well-marked area, but apparently no deltidium.[4] In the hollow beak there is a small median septum from which two prongs project in front of the hinge-line. Interior of ventral valve granulose. Dorsal valve with the usual type of cardinal process and bridge. Median septum not branched, tapering behind to a sharp point. Brachial lamellæ attached to the end of the septum and curving forwards on each side parallel with the margin of the shell to near the front of the septum, when they are reflected back along the sides of the septum. The margin of the valve, the front of the septum, and the bridge are covered with granules.

Thecidellina differs from *Lacazella* in the presence of the prongs on the septum of the ventral valve instead of a muscular plate, and in the unbranched septum and simpler lamellæ of the dorsal valve. The dorsal valve is very similar to that of the Liassic *Thecidella*, in which, however, no bridge has been described and the septum is not acicular but broadly rounded. Moreover, a well-defined deltidium is present in this genus.

Thecidellina includes the recent tropical forms *T. Barretti*, Davidson (Jamaica) and *T. maxilla*, Hedley (Funafuti and New Hebrides) and a new species described below from the Tertiary (Oamaruian) of New Zealand. The discovery of the last adds additional weight to the argument that the Oamaruian of New Zealand enjoyed a warmer climate than the present, since the two recent species of the genus have a tropical distribution.

The only other Tertiary member of the Thecidiinæ so far found in the Southern Hemisphere is *Thecidium australe*, Tate,[5] from the Muddy Creek beds, Victoria. The interior of the dorsal valve of this

[1] Cf. Siemiradzki, Bull. Intern. Acad., 1909, p. 768 (*vide* Zool. Record).

[2] *Thecidium*, Sowerby, 1824, is a synonym of *Thecidea*, Defrance, 1822, and is still often erroneously used for *Thecidea*.

[3] Mem. Austral. Mus., No. 3, pt. viii, p. 510, 1899.

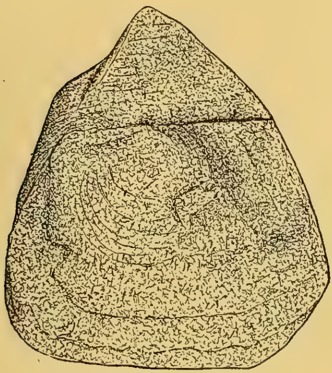
[4] Cf. Hedley, loc. cit.

[5] Trans. Roy. Soc. S. Austral., vol. iii, p. 116, pl. ix, figs. 3*a*–*c*, 1880.

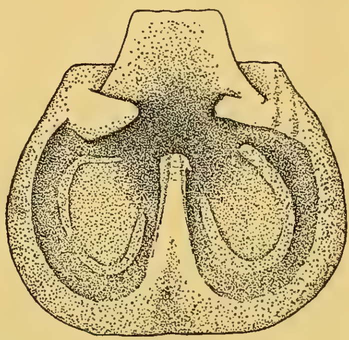
species is unknown, but the presence within the umbo of the ventral valve of a "cup-shaped cavity divided longitudinally by a median septum" seems to connect it with *Lacazella*. All the Tertiary forms of Europe to the literature of which I have access belong also to *Lacazella*, viz. *L. Adamsi*, McDonald, from the Miocene of Malta, *L. testudinarium*, Michelotti, from the Miocene of Italy, and *L. latdorfiense*, Davidson, from the Oligocene of Germany, and the genus has also European Cretaceous representatives.

THECIDELLINA HEDLEYI, sp. nov.

Description.—Shell attached by the beak of the ventral valve, irregular in shape but in dorsal aspect rounded trigonal with a nearly straight front, greatest width near the anterior margin. Dorsal valve nearly flat, irregularly waved, raised near the umbo. Ventral valve strongly convex, oyster-like; commissures practically plane.



a



b

FIG. 1.—*Thecidellina hedleyi*, Thomson, Kakanui, New Zealand (enlarged 10 diameters). (*a*) Holotype, dorsal view; (*b*) paratype, interior of dorsal valve, ventral view.

Hinge-line straight, moderately broad, beak sharp, without foramen, area triangular, flat. Interior of dorsal valve: socket ridges converging slightly posteriorly and uniting mesially to form a process which is subrectangular and projects posteriorly considerably beyond the hinge-line, and is concave anteriorly. In front of the socket ridges there are two spurs pointing laterally inwards, probably the remains of a broken bridge. The margin is granulated, and is produced into a median septum, low anteriorly, rising posteriorly, and reaching a little beyond the middle of the shell. From this septum two lamellæ probably curved laterally forwards on each side, but are now disconnected in the specimen available. The granulations do not continue from the margin to the septum. Interior of ventral valve unknown.

Dimensions in millimetres:

	Length.	Breadth.	Thickness.
Holotype	2·7	2·5	1·2
Paratypes	2·8	2·0	1·5
	2·6	2·1	1·2

Type Locality.—Everett's limestone quarry, Kakanui, New Zealand.

Horizon.—Oamaruian (probably Miocene).

Material.—Holotype and four paratypes; one of the latter consists of a dorsal valve only.

Remarks.—The Kakanui limestone consists largely of hollow or partially filled shells of Brachiopods, a peculiarity of fossilization being that the pores of the shells are obscured, so that in many undoubtedly punctate shells, such as *Terebratula oamarutica*, Boehm, the punctation cannot be distinguished even under a microscope. The specimens of *Thecidellina hedleyi* are of a dull white colour and show no sign of punctation, but it does not necessarily follow that it is absent. No trace of deltidium can be seen, and this is in agreement with *T. maxilla*, Hedley. In external form *T. hedleyi* has more resemblance to *T. Barretti* than to *T. maxilla*, but is more nearly trigonal than either of these species.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science, Eighty-fifth Annual Meeting, held at Manchester, September 7–11, 1915. List of Authors and Titles of Papers read in Section C (Geology).

Presidential Address by *Professor Grenville A. J. Cole, F.G.S.*

Dr. G. Hickling.— Address on the Geology of Manchester and District.

Professor E. J. Garwood, F.R.S.—On the discovery of *Solenopora* and *Sphærocodium* in Silurian Rocks of Britain.

Hon. Professor W. Boyd Dawkins, F.R.S.—The Classification of the Tertiary Strata by means of the Eutherian Mammals.

Hon. Professor W. Boyd Dawkins, F.R.S.—The Geological Evidence of the Antiquity of Man in Britain.

Joint Discussion with Section E on the Classification of Land Forms. Opened by *Dr. J. D. Falconer.*

Canon T. G. Bonney, F.R.S.—Notes on the North-West Region of Charnwood Forest.

Professor W. W. Watts, F.R.S.—Note on Granite Surfaces of Mount Sorrel.

Dr. A. H. Cox & Mr. A. K. Wells.—The Ordovician Sequence in the Cader Idris District (Merioneth).

Professor W. G. Fearnsides.—A Contour Map of the Barnsley Seam of Coal in Yorkshire.

Mr. E. S. Cobbold.—Sixth Report on Excavations among the Cambrian Rocks of Comley, Shropshire.

Professor W. J. Sollas, F.R.S.—On the Restoration of certain Fossils by Serial Sections.

Dr. D. M. S. Watson.—Vertebrate Life Zones in the Permo-Trias.
Professor R. C. Wallace.—The Corrosive Action of Brines in Manitoba.
Dr. A. Wilmore.—Carboniferous Limestone Zones of North-East Lancashire.
Mr. H. Day.—A brief Criticism of the Fauna of the Limestone Beds at Freak Cliff and Peakshill, Castleton.
Dr. Arthur Vaughan.—On the Shift of the Western Shore-line in England and Wales during the Avonian Period.
Dr. Albert Jowett.—A Preliminary Note on the Glacial Geology of the Western Slopes of the Southern Pennines.
Reports of Research Committees.
Discussion on Radio-active Problems in Geology. Opened by *Professor Sir E. Rutherford.*
Professor C. A. Edwards.—Twinning in Metallic Crystals.
Dr. J. W. Evans.—The Isolation of the Directions Image of a Mineral in a Rock-slice.
Dr. G. Hickling.—On the Micro-structure of Coal.
Mr. Thomas Crook.—On the Economic Mineral Products of Damaraland, South-West Africa.
Mr. W. Lower Carter—Committee to consider the preparation of a List of Characteristic Fossils.
Professor E. W. Skeats.—Committee to consider the Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere.
Dr. F. A. Bather.—Committee to consider the preparation of a List of Stratigraphical Names used in the British Isles, in connexion with the Lexicon of Stratigraphical Names in course of preparation by the International Geological Congress.
Professor W. G. Fearnsides.—Committee to excavate Critical Sections in Lower Palæozoic Rocks of England and Wales.
Professor Grenville A. J. Cole.—Committee to investigate the Old Red Sandstone Rocks of Kiltorcan, Ireland.

Section E.—Geography.

Presidential Address by *Major H. G. Lyons, F.R.S.*
Professor J. W. Gregory, F.R.S.—Relations of the Central Lakes of Westralia.

II.—*Papers read before Section C (Geology), British Association, Manchester, September, 1915.*

(1) On the Underground Contours of the Barnsley Seam of Coal in the Yorkshire Coalfield. By W. G. Fearnsides, M.A., F.G.S., Sorby Professor of Geology, University of Sheffield.

In this paper the author presents a preliminary account of the results of his statistical analysis of about a hundred records of borings and sinkings which have proved the depth of the Barnsley Bed or its equivalents (the Gawthorpe, the Warren House Coals of Yorkshire, and the Top Hard Coal of Derbyshire) in Yorkshire. The majority of the records of borings and sinkings discussed have been collected by a committee of the Midland Institute of Mining, Civil, and Mechanical Engineers, and were published by that institution in volume form in 1914, the sites at which the information was obtained being plotted on a half-inch map. The depths to the coal have been corrected for the height of the surface location above sea-level, and, after the manner of Dr. Gibson's map (plate i) in the Geological Survey Memoir on the Concealed Coalfield (1913), contour-lines have been drawn among the spot-levels so obtained. Other contour-lines similarly obtained from the records of borings which have passed through Permian strata show the character of the surface of the Coal-measures where they underlie the Permian strata.

In drawing the contour-lines no attempt has been made to distinguish between those changes of level in the seam between neighbouring pits which are due to faulting, and those due to the folding of the strata. Since, however, over most of the coalfield the faults tend to nullify the change of level which the dip has accomplished, it is maintained by the author that to plot contours which show the average rate of change of level is a statistical method which yields a useful presentation of the truth.

1. From an analysis of the results as plotted it appears that the underground contours of the Barnsley Bed (strike lines) in Yorkshire in detail generally range either N.E.–S.W. or N.W.–S.E., and that within the area under which the Barnsley Bed has actually been proved by working it is difficult to find either a N.–S. or an E.–W. strike constant over more than a very few miles of country. This circumstance, if general over the coalfield, would seem to demand some revision of current views respecting the origin and structure of the Pennine Chain.[1]

2. The greatest structural division of the coalfield 'basin' is by the equivalent of a N.E.–S.W. anticline of which the southern limb is along the line of the Don faults from Sheffield by Rotherham and Conisborough to Doncaster. North of this line there is some evidence for the existence of a completed syncline, with its axis central near Frickley. In ground from which the Permian rocks have been denuded, the Barnsley coal attains a depth exceeding 1,800 feet below sea-level. The general line of this northern trough follows a N.W.–S.E. trend from Wakefield to South Kirkby, whence, displaced perhaps by the Don anticline, it bends somewhat eastward through Bulcroft. South of the Don a wider trough, also trending N.W.–S.E. through Yorkshire Main Colliery (Edlington) and Bawtry, carries the Barnsley Bed (at Rossington) below 2,600 feet.

3. The inclination of the Barnsley Bed is at its steepest near the outcrop, and after the manner of gentle folds the measures flatten

[1] These views were admirably expressed by Professor E. Hull, who in advocating them in 1868 succinctly remarked (Q.J.G.S., 1869, p. 331): "Immediately upon the close of the Carboniferous period the northern limits of the Yorkshire and Lancashire Coalfields were determined by the upheaval and denudation of the beds along east and west lines, while the coalfields themselves remained in their original continuity across the region now formed of the Pennine hills from Skipton southwards, and that at the close of the Permian period these coalfields were dissevered by the uprising of the area now formed of the Pennine range by lines of upheaval ranging from north to south."

out when the centre line of the syncline is approached. There is no evidence to suggest any general eastward rise of the Barnsley Seam within the area plotted on the map. (The eastern boundary of the map is through Thorne and Retford.)

4. By the plotting of the contour-lines on Bartholomew's layer-coloured half-inch contour map, the interdependence of underground structure and topographical relief in the area of the exposed coalfield has been well brought out. Over the whole coalfield most of the ridges are of escarpment form and are elongate along the line of strike, but from the map it becomes evident that wherever the strike of the Barnsley Bed shows a change of direction, there the escarpment ridges are found upstanding above their average height, and this whether they form the arches or lie in the troughs of the folds.

From his experience of the application of the contour method to the study of the tectonics of the Barnsley Bed, the author suggests that the method is of peculiar usefulness in coalfield work. He offers this preliminary account of the results of his work in Yorkshire in the hope that workers on the western side of the Pennines may take up the method and use it in the further investigation of the many and difficult problems of geological structure presented by the 'Backbone of England'.

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(2) A Brief Criticism of the Fauna of the Limestone Beds at Treak Cliff and Peakshill, Castleton, Derbyshire. By Henry Day, M.Sc.

THE author put forward some observations on a collection of some three hundred species of Carboniferous Limestone fossils from the localities Treak Cliff and Peakshill, Castleton, and embracing about one hundred species of Brachiopods and Corals. The beds at both places may be referred to the 'Brachiopod beds' of Sibly (Q.J.G.S. 1908), which are allocated by him to sub-zone D_2—the Lonsdalia sub-zone. The present list of species presents some features of considerable interest bearing on the value of certain types as zonal indices. Reference is made to Vaughan's paper on the Bristol area, where it is indicated that amongst the Brachiopod groups confined to the Tournaisian in that area are the following: *Productus* cf. *Martini*, *Leptena analoga*, *Schizophoria resupinata*, *Rhipidomella* aff. *Michelini*, *Spiriferina octoplicata*, *Syringothyris cuspidata*. Two of these, it is noted, *Spiriferina octoplicata* and *Schizophoria resupinata*, are sub-zonal indices, and each with its maximum in its sub-zone. The list of Castleton forms from well up in D, now presented, includes all the above-mentioned Brachiopod groups. *Syringothyris cuspidata* and *Spiriferina octoplicata* are fairly abundant at both Treak Cliff and Peakshill, *Schizophoria resupinata* is extremely abundant at both places, *Leptena analoga* is abundant, whilst *Productus* cf. *Martini* and *Rhipidomella Michelini* are rare.

Passing to the coral fauna, the genus *Zaphrentis* appears in the Castleton list, i.e. one of the two genera of Corals confined to the Tournaisian in the Bristol area and not extending into the Viséan. The genus, though not very abundant, is represented by several species. In addition, the genera *Michelinia* and *Amplexus*, characteristic of the Upper Tournaisian of Bristol, but possibly extending into the base of the Viséan, are cited in the Castleton list, *Michelinia glomerata* being fairly abundant at Peakshill, and *Amplexus coralloides* is found at Treak Cliff, but is extremely rare.

These facts lead to a consideration as to how far the types mentioned are of value in zonal determinations. If any one of them, as recorded from Castleton, be regarded as representing exactly the same form as that recorded from the Bristol area, then its value as one of a number of index fossils of a zone becomes negligible. Examples are cited in the cases of *Spiriferina octoplicata* and *Schizophoria resupinata*. If the Castleton forms of D_2 horizon agree in identity with the Bristol types of K_2 and Z_2 respectively, then these two types become worthless as sub-zonal indices. It was pointed out that, even allowing of the rather unlikely possibility that in all the cases cited the Castleton specimens represented mutational forms of the Bristol species, the real difficulty as to their zonal value is not overcome, since the line of demarcation between mutations is more or less arbitrary, and there is still a considerable field of discussion as to what constitutes a 'mutation'.

It appears probable that any system of zonal indices can be of local value only, as for example in the application of the Bristol zonal indices within the Bristol area, and cannot be of any general application.

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(3) A Preliminary Note on the Glacial Geology of the Western Slopes of the Southern Pennines. By Albert Jowett, D.Sc., F.G.S.

THE area dealt with extends from Blackstone Edge southwards to the southern extremity of the Pennines.

No striated surfaces of solid rock have been discovered at high levels, and the two that have been recorded at Salford and Fallowfield serve only to indicate a general movement from N.W. to S.E. For more detailed information as to the movements of the ice-sheet, the only evidence is that afforded by the distribution of the drift at high levels and by the systems of drainage along the edge of the ice. From this it may be inferred that the main directions of ice movement about the time of the maximum extension of the ice-sheet were roughly towards the north-east in the Tame Valley, the east in the Etherow Valley, and the south-east and south-south-east in the Goyt Valley and further south. These directions were much modified locally by the complicated configuration of the sub-glacial surface.

The first barrier of hills met with on approaching the Pennines from the South Lancashire and Cheshire plain was almost everywhere overridden by ice, which left definite deposits of drift with foreign rocks at altitudes up to 1,360 feet, and scattered erratic boulders up to 1,400 feet. As this foreign drift penetrates further into the hills its maximum altitude falls steadily. It has only been traced across the main Pennine divide at the broad col (1,100 feet above O.D.) south-east of Chapel-en-le-Frith.

Thick deposits of drift and big erratics are comparatively rarely met with at the extreme limit of the foreign drift, towards which the erratics generally diminish in number and in size. Boulders of local rocks, often obviously transported and uplifted beyond their parent outcrops, become relatively more abundant towards the limit of the foreign drift, and generally form a spread of drift extending beyond it and passing insensibly into the driftless area.

Great lakes were held up by the ice barrier some time after it commenced to retreat from the western slopes of the Pennines. During early stages in this retreat the drainage from the lakes in and north of the Etherow Valley escaped northwards, and ultimately passed through the Walsden Gap into the Calder. When the ice barrier east of Manchester fell below 600 feet above O.D., this drainage followed the course of that south of the Etherow Valley and escaped southwards.

The action of the ice-sheet with its associated streams of water, together with the marginal water derived from melting ice and draining from the region beyond the ice-sheet, assisted by the action of post-glacial streams, in depositing the original drift, in cutting new channels through rock and drift, and in resorting and redepositing the debris, seems quite sufficient to account for the complicated superficial deposits in this area.

No evidence has been found of more than one period of glaciation nor of any local glacier system. There are, however, curious corrie- or cirque-like features, e.g. on Shelf Moor, Glossop. Moreover, although the Pennines are on the whole much lower north of the Etherow Basin than further south, the overflow channels of glacier lakes can be found at higher altitudes in the former than in the latter region. This is the reverse of what might be expected if the higher ground were ice-free. It may be, therefore, that at and near the time when the ice-sheet attained its maximum development the snow-line actually descended below the altitude of the higher Pennine hills, and, without bringing about a definite local glaciation, temporarily filled the higher hollows with snow up to the general level of the ridge. Thus, instead of the margin of the ice-sheet at that stage melting away rapidly, melting might be considerably reduced and even temporarily suspended, and the ice-sheet reinforced by the local snowfall. Such conditions would tend to depress the limit of distribution of erratics immediately west of the highest ground, but where an ice-stream carrying erratics actually crossed the watershed they might lead to the distribution of those erratics further and more widely than otherwise might have been possible.

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(4) The Old Red Sandstone Rocks of Kiltorcan, Ireland. Report of the Committee, consisting of Professor Grenville Cole (Chairman), Professor T. Johnson (Secretary), Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.

The Committee has spent the sum of £5 from the unexpended balance of the grant made in 1913, and has returned the remaining balance to the General Treasurer. The grant of £10 made in 1914 was not called on, since the work for which it was specially intended, excavation at Tallow Bridge, proved impracticable, owing to local difficulties. The regular working of the Kiltorcan quarry, however, makes it desirable to secure good specimens as they are turned out, since the owner is the local contractor for roads, and the stone and plant-remains become alike used in making the Kilkenny highways. Short of actual purchase and preservation of the historic site, the alternative is to pay the owner to watch the work as it goes on and to set aside the more interesting material. He has shown a ready appreciation of the requirements of the Committee.

Hence the Committee asks for its continuance and a grant of £10 for the excavation work at Kiltorcan, and for specimens obtainable in 1915–16.

The Committee would be glad to be allowed to send, carriage forward, duplicate material of *Archæopteris*, *Bothrodendron*, *Archanodon*, etc., to the botanical and geological sections of universities, colleges, and museums in the British Empire, where it is found that such specimens would be welcome. Such gifts would, of course, be accompanied by a statement as to the auspices under which the material was obtained.

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(5) The Geological Evidence in Britain as to the Antiquity of Man. By Hon. Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S.

PROFESSOR BOULE, in his masterly essay published in *Anthropologie*, xxvi, Jan.-Avril, 1915, freely criticized the evidence on which the antiquity of man in Britain has been stated to go back beyond the early Pliocene age, and concludes that it is not of a nature to throw light on so important a problem. The antiquity of man—or, in other words, his place in the geological record—is a geological question to be decided, like all others, on the lines of a rigid induction. In each case it is necessary to prove, not only that the objects are of human origin, but further that they are of the same age as the strata in which they occur, without the possibility of their having been introduced at a later time. In this communication I propose to apply these tests to the evidence.

The Pliocene age of man in East Anglia is founded entirely on the roughly chipped flints in the basal Pliocene strata—on eoliths, mainly of the rostro-carinate or eagle's-beak type of Moir and Lankester. It has been amply proved in this country by Warren, Haward, and Sollas, and in France by Boule, Breuil, and Cartailhac, that these can be made without the intervention of man by the pressure and movement of the surface deposits, by the action of ice, by the torrents and rivers, and by the dash of the waves on the shore. The type-specimens taken to be of human work have been selected out of a large series of broken flints that graduate into forms obviously made by natural fractures. They are, as Boule aptly says, "hypersélectionnées," and can only be rightly interpreted by their relation to the other flints on the Pliocene shore-line.

As might be expected, if they are due to natural causes, the 'rostro-carinates' are widely distributed through the basal beds of the Crag in Norfolk and Suffolk. They occur also in the Upper Miocenes of Puy-Courny (Auvergne), in the Pleistocene gravels of London, and the present shore-line of Selsey, where they are now probably being made by the breakers. For these reasons I agree with M. Boule that they have not been proved to have been made by man, and that therefore they throw no light on his place in the geological record.

The presence of man in East Anglia during the Glacial period is founded on even worse evidence than this. The Ipswich skeleton on which Moir and Keith base their speculations was obtained from a shallow pit sunk through the surface soil of decalcified boulder-clay—not of boulder-clay in situ, as stated—into the Glacial sand that crops out on the valley slope. It is, in my opinion, a case of interment that may be of any age from the neolithic to modern times. The skeleton also is of modern type, and belongs, as Duckworth shows, to the graveyard series of burials.

We come now to the consideration of the evidence of the famous discovery on Piltdown of *Eoanthropus Dawsoni*—the missing link between primitive man and the higher apes. After the examination of the whole group of remains, and a study of the section, I fully accept Dr. Smith Woodward's opinion that the find belongs to the early Pleistocene period. The associated implements are of the same Chellean or Acheulean type as those so abundant in the mid-Pleistocene Brick-earths of the Thames Valley between Crayford and Gravesend. They may imply that *Eoanthropus* belongs to that horizon, in which the stag is present and the reindeer absent. It must not, however, be forgotten that the classificatory value of these implements is lessened by their wide range in Britain and the Continent through the later Pleistocene River deposits. The stag, the beaver, and the horse of Piltdown—leaving out of account the Pliocene fossil mammals more or less worn into pebbles—are common both to the pre-Glacial Forest-bed and the Lower Brick-earths of the Thames Valley and the later Pleistocene River-deposits. It must also be noted that the intermediate characters of the Piltdown skull and lower jaw point rather to the Pliocene than the Pleistocene stage of evolution. We must, in my opinion, wait for further evidence before the exact horizon can be ascertained. On the Continent there is no such difficulty.

The earliest traces of man are there represented at Mauer by a mandible associated with the peculiar fauna of the Forest-bed, showing that *Homo Heidelbergensis*, a chinless man, was living in the Rhine Valley during the earliest stage of the Pleistocene. The Neanderthal man, thick-skulled and large-brained, with small chin and stooping gait, belongs to the Mousterian stage, that, in my opinion, is not clearly defined from the Chellean and Acheulian gravels of the late Pleistocene. He ranged from the Rhine through France southwards as far as Gibraltar, and was probably the maker of the Palæolithic implements of those strata throughout this region. It is also probable that he visited Britain, then part of the Continent, in following the migration of the mammalia northward and westwards across the valley of the English Channel. While primitive men of these types inhabited Europe there was no place in the Pleistocene fauna for the thin-skulled men taken by Dr. Keith[1] and others to prove that modern types of men lived in Britain in the Pleistocene age.

Man appears in Britain and the Continent at the period when he might be expected to appear, from the study of the evolution of the Tertiary Mammalia—at the beginning of the Pleistocene age when the existing Eutherian mammalian species were abundant. He may be looked for in the Pliocene when the existing species were few. In the older strata—Miocene, Oligocene, Eocene—he can only be represented by an ancestry of intermediate forms.

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(6) The Classification of Land Forms. By Dr. J. D. Falconer, M.A.

THE investigation of processes is the common ground of geology and geography. The geographical processes, however, are less numerous than the geological and are studied by geologists and geographers with a different purpose. The geologist studies these processes in order to elucidate the past history of the earth, the geographer in order to systematize the present topographical features of the surface. Geological interest in the geographical processes thus ceases as soon as the so-called land forms have been referred to their respective processes or combinations of processes. Since most text-books of physical geography have been written from the geological point of view, it follows naturally that the treatment of land forms in these textbooks is entirely subsidiary to the discussion of processes and offers no clue to the scientific definition and classification of individual forms. It is believed, however, that these submit themselves to systematic classification with almost as much ease as the subject-matter of other natural sciences, and that it falls clearly within the scope of geography as the science of the earth's surface to establish such a classification. The first attempt in this direction was made by Professor Passarge, of Hamburg, in 1912.[2] The classification outlined below is based upon similar principles and has already appeared in the *Scottish Geographical Magazine*.[3]

It is proposed to set up two classes of land forms, each containing two orders—

Class A. Endogenetic Forms.
Order I. Negative Forms.
Order II. Positive Forms.
Class B. Exogenetic Forms.
Order I. Degradation Forms.
Order II. Aggradation Forms.

The two orders of endogenetic forms are then subdivided into four families—

Family 1. Forms due to superficial volcanic activity.
2. ,, ,, sub-crustal volcanic activity.
3. ,, ,, radial movements.
4. ,, ,, tangential movements.

[1] The skeletons of Galley Hill, in Kent, and probably that of Cheddar cave in Somerset, have, in my opinion been buried, and do not belong to the Pleistocene age. They are either prehistoric or even historic.

[2] Mitt. der Geog. Gesell. in Hamburg, xxvi, p. 133, 1912.

[3] xxxi, p. 57, 1915.

Similarly, the two orders of exogenetic forms are each subdivided into nine families—

Family 1.	Forms due to the action of the run-off.			
2.	,,	,,	,,	percolating water.
3.	,,	,,	,,	streams and rivers.
4.	,,	,,	,,	life.
5.	,,	,,	,,	lightning.
6.	,,	,,	,,	sun heat.
7.	,,	,,	,,	the atmosphere.
8.	,,	,,	,,	frozen water.
9.	,,	,,	,,	the sea.

Each family is then subdivided into genera and species or specific forms. It is suggested that a land form be defined as any surface or slope which may be referred in origin to the operation of a single process or force. Monodynamic surfaces of this kind being rare, however, the commoner polydynamic surfaces may be classified according to the predominant force amongst those responsible for the production of the surface. This definition may be extended to include such surface features as cones or domes enclosed by one continuous surface, or such features as ridges or mounts enclosed by surfaces meeting in edges, provided that all these surfaces may be classified as examples of the same specific form.

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(7) The Isolation of the Directions Image of a Mineral in a Rock-slice. By J. W. Evans, D.Sc., LL.B.

The author discussed the different methods by which the interference figures of a small mineral in a rock-slice may be kept distinct from those of adjoining minerals. He recommended two. In one, which he believes to be new, a diaphragm with a small aperture is placed below the condenser, which is lowered till the image of the aperture appears in focus on the rock-slice. In some microscopes the iris diaphragm provided for the Becke method of determining the refractive index may be employed. In others it is too near the condenser. The aperture should be sufficiently large to illuminate the maximum area of the mineral under investigation, but no portion of the others. The directions image may then be observed in any of the usual ways. Unless the condenser and diaphragm revolve with the stage the aperture must be very carefully centred with the axis of rotation.

The other method was proposed by Becke in 1895, but is very little known. The diaphragm is placed in the focus of the eye-piece so as to shut out all except the mineral selected. The Becke lens, or system of lenses resembling an eye-piece, is placed above the eye-piece, when the directions image of the mineral will be seen without any admixture of light from its neighbours. This method has the advantage that the diaphragm is less highly magnified at the time of adjustment. When a rotating stage is employed, a very accurate centreing of the nose-piece of the microscope is required, so that the coincidence of the object with the aperture may be maintained.

The common practice of placing a diaphragm for this purpose immediately below the Bertrand lens rests on no scientific basis, and is not effective in shutting out the light of minerals other than that which is being studied.

REVIEWS.

I.—Catalogue of the Mesozoic Plants in the British Museum (Natural History). The Cretaceous Flora: Part II. Lower Greensand (Aptian) Plants of Britain. By Marie C. Stopes, D.Sc., Ph.D. 8vo; pp. xxxvi + 360, with 112 text-figures and 32 plates. Trustees of British Museum. London: Dulau & Co., 37 Soho Square, W., 1915. Price 21*s.*

WE heartily congratulate the author of the volume, and the Department of Geology which is responsible for its publication, on the appearance of this second instalment of the Catalogue of the Cretaceous Flora. Dr. Stopes is well qualified for the task of investigating the often unpromising fragments upon the study of which a knowledge of this flora is based, and the book is a record of careful painstaking research. It appeals essentially to the botanist, who will examine with admiration the photographs, and more especially the line drawings, in which Dr. Stopes illustrates the histological structure of the species she is describing. In preservation of detail many of these Lower Greensand species are equal to the remarkable specimens with which we have become familiar in the Coal-measure petrifactions. As the author reminds us, the plants of the Lower Greensand in this country are found under very favourable conditions, occurring in a well-defined and well-known marine deposit. The principal localities are the coasts of the Isle of Wight, the quarries of North Kent near Maidstone and Ightham, near Woburn and Potton in Bedfordshire, and near Leighton Buzzard in Bucks. Forty-five forms are described, comprising one Thallophyte (*Chondrites Targionii*), two Ferns, nine Cycadophyta, twenty-seven Conifers, and five Angiosperms. As compared with other Mesozoic floras the list is remarkable for the scarcity of Ferns and the great preponderance of Conifers. In the Wealden flora, on the other hand, the Ferns head the list and the Conifers are relatively few, while Angiosperms are unrepresented. The Aptian flora is characterized by absence of leaf-structures, and is composed mainly of woody stems with a fair sprinkling of gymnospermic cones. These characters are explained by the nature of the deposits, which represent "a narrow arm of the sea in which a coarse marine detritus was being laid down at no great distance from land". The plant remains must have drifted for some time before they were entombed, and this resulted in the elimination of all the soft leaves. The only well-preserved leaf is that of a twig of *Sequoia* which had become sheltered in the stem of a larger plant. Hence the absence of herbaceous plants does not imply their non-existence in the flora, and, as the author points out, does not support the view that the woody tree is the primitive type of Angiosperm. The five genera of Angiosperms described are the earliest Dicotyledons recorded for the North of Europe, and the earliest specimens of which the anatomy is known from any part of the world, but Dr. Stopes wisely refrains from adding to the burden of the discussion of the origin of Angiosperms. The species studied "were woody plants of a highly advanced and differentiated character, and there is nothing in their anatomy to indicate any more clearly their phylogenetic origin than there is in the stems of the still living genera". But she does not favour the *Bennettites* solution, and suggests that the existence of highly differentiated Angiosperms in the strata from which the typical *Bennettites Gibsonianus* and others were obtained adds to the improbability of a Bennettitalian ancestry for the Angiosperms.

As regards the climate of the Aptian period, the inference is drawn that it was relatively cool with well-marked seasons, thus contrasting with the more tropical climate of the preceding Wealden and succeeding Gault and Upper Greensand. The inference is based on the large number of Abietineæ and the absence of Araucarineæ among the Conifers, and the well-marked annual rings in the wood of the latter.

The account of the Coniferous woods is prefaced by a useful discussion of the histological characters which may be regarded as supplying trustworthy data for systematic determinations; and the writer condemns the use of various minute details which prove to be merely individual variations and to have no specific value.

As regards the plants enumerated, the two Ferns are previously described species of *Weichselia* and *Tempskya*; an interesting restoration of *T. rossica* is depicted, provided by Dr. Kidston and the late Professor Gwynne-Vaughan, whose untimely death leaves a serious gap in the ranks of workers on plant anatomy. Cycadophyta are represented by *Bennettites*, including a new species, *B. Allchini*; *Cycadeoidea*, also with a new species from the classic locality for *C. Yatesii*; a new genus *Colymbetes*, with a remarkable stem anatomy, perhaps from the same locality; and two doubtful specimens. The Coniferales include a *Sequoia*, very near to the living *S. gigantea*; new species of *Protopiceoxylon* and *Pityoxylon*; species of *Pinostrobus* and *Cedrostrobus*; new species of *Cedroxylon* and *Cupressinoxylon*, in addition to the previously described *Cupr. vectense*, Barber; new species of *Taxoxylon* and *Podocarpoxylon*; and a remarkable specimen known only from a mass of secondary tissue, the position of which is doubtful; it is described as *Vectia luccombensis*. The five dicotyledonous Angiosperms are founded on as many specimens, and correspond to no previously known genera. Dr. Stopes is unable to assign them to any existing family, but tentatively suggests that one, *Woburnia*, may be a Dipterocarp.

A. B. Rendle.

II.—Meteorites.

1. Victorian Meteorites. — In Memoir No. 6 of the National Museum, Melbourne (pp. 66, with 5 plates, April, 1915), Mr. R. Henry Walcott describes very fully the Victorian meteorites and adds some notes on obsidianites. The meteorites comprise the three Cranbourne, including the Yarra Yarra fragments, Beaconsfield, and Langwarrin meteorites, which are shown to be probably remains of one fall, and the Bendoc, Yarroweyah, and Kulnine meteorites. Their history and characters are in each case discussed in detail. The best known of them is the Cranbourne, of which No. 1, the largest, weighing about 3½ tons, is in the Natural History Museum, London, and No. 2,

weighing 30 cwt., is in the Melbourne Museum; No. 3 has disappeared. Unlike the larger mass, No. 2 appears to have exuded very little chloride of iron, and no scaling has been observed. The Bendoc and Yarroweyah irons are both in the Melbourne Museum; they weighed 60 lb. and 21 lb., and were discovered in 1898 and 1903 respectively. The Kulnine iron, which weighed 122 lb., and was found in 1886, is in the Adelaide Museum. A table of chemical analyses and a full bibliography are given. The author concludes that the obsidianites (australites), though glassy in character, are undoubtedly meteoric in origin.

2. Meteoric Irons from the Klondike Mining District, Yukon.—In the Museum Bulletin No. 15 of the Geological Survey of Canada (pp. 8, with 11 plates, June 30, 1915), Mr. R. A. A. Johnston describes the meteoric irons found in the course of gold-mining operations in Gay Gulch and Skookum Gulch, both tributary to the Bonanza Creek system in the Klondike mining district, Yukon. The former weighed 483 grams and was found in 1901. The latter, which was discovered on January 21, 1905, was much larger; it measured 29 cm. in length, 23 cm. in width, and 3 to 8 cm. in thickness, and weighed 15·88 kilograms. Both specimens were acquired by the Ottawa Museum. From the similarity in the characters of the two irons, both being exceptionally rich in nickel and exhibiting a peculiar chatoyancy in sections, and in their positions, both lying on the bedrock under the 'white channel' gravels, as the miners term the ancient creek deposits, the author considers that they are relics of a single meteoric shower, which occurred in Tertiary time.

CORRESPONDENCE.

COAST EROSION IN NORFOLK.

Sir,—On September 1 of this year I found the well-known tower of Sidestrand old Church, near Cromer, now on the very edge of the cliff: a rabbit could not pass between. It had begun to crack, and its fall may come at any time. On April 27, 1905, I made a rough map of churchyard, tower, and cliff-edge; and noted the distance between tower and cliff-edge as then 7 feet. I record this as a contribution towards estimates of cliff-waste on this coast.

In the Geological Magazine, 1895, pp. 229, 230, are calculations of rate of inland retreat for the sand-dunes at Eccles, 12 miles south-east. The calculations give a retreat of somewhere about 130 feet in seventy-seven years.

E. Hill.

The Rectory, Cockfield, Bury St. Edmunds.
September 15, 1915.

HUMAN PALÆONTOLOGY IN ENGLAND.

Sir,—The current number of *L'Anthropologie* (January–April, 1915), I notice, contains a paper by M. Boule entitled "La paléontologie humaine en Angleterre", which is the most extraordinarily biassed statement it has ever been my ill-fortune to read.

M. Boule in this paper refers especially to the flaked flints found beneath the Red Crag of Suffolk, and also to the human skeleton found by me in Messrs. Bolton & Laughlin's sand-pit at Ipswich in 1911, and in criticizing these discoveries has certainly lived up to the view expressed on p. 38 of his paper that it is better to be too severe in criticisms of such matters than not to be severe enough. In this note I propose to emulate M. Boule's 'severity', and to speak out plainly as he has done. But I do not intend to make any reply to the threadbare and foolish arguments he uses in support of his case, arguments which I have replied to a great number of times, and which I do not intend to discuss any further. I want, however, to say something about M. Boule's and his colleague M. Breuil's attitude towards the discoveries I have mentioned, and their capabilities of judging whether a flint has been flaked by nature or by man. Regarding the first, I am of the opinion that both M. Boule and M. Breuil are hopelessly biassed in favour of the view that the human race is not more ancient than the early Chellean period, and I hold this view for the following reasons. It has come to my knowledge from an unimpeachable source that many weeks before either of these gentlemen visited Suffolk or had seen a single one of my specimens, they had expressed their disbelief in the value of my discoveries. I also know, from personal observation, that when they were here they showed very plainly and unmistakably that they did not intend to examine carefully and scientifically the sub-Crag flints or the beds from which they were derived, nor did they spend more than a few minutes in examining the section in the pit where the Ipswich skeleton was found. Their attitude to all the things they saw was careless and almost petulant, and in my opinion quite unscientific. Regarding the capabilities of MM. Boule and Breuil of judging whether a flint has been flaked by nature or by man, I am of the opinion that neither of them is capable of such judgment, and I hold this opinion for the following reasons. After the sub-Crag flints had been seen and rejected as humanly fashioned I showed M. Boule a series of the Middle Glacial specimens, and without telling him from what stratum they were derived asked whether he regarded them as 'human' or 'natural'. He at once said he thought they were definite implements of man. I then told him where they were found, and immediately he disputed the correctness of the geological interpretation. When, however, I showed him that this interpretation was undoubtedly correct, he said that the flints could not be humanly fashioned. I notice at p. 13 of M. Boule's paper he describes these Middle Glacial specimens as "formes troublantes", and I can quite understand why he so regards them. On the morning of the second day of the visit of MM. Boule and Breuil I showed the latter a flint scraper found beneath the shelly Red Crag, which in form was identical with the scrapers which are found in nearly every period of the Stone Age, and asked him whether he considered it to be humanly fashioned or flaked by natural forces. He replied that it was his opinion that nature was responsible for the flaking. I then asked him to tell me what force he considered had flaked the flint, and he simply shrugged his shoulders and said he did not know. Now regarding M. Boule's statement about the Middle Glacial flints it is evident that he does not know the difference between a humanly fashioned flint and one that has been flaked by nature, because he first of all stated these Middle Glacial specimens were 'human', and then when he was told the deposit from which they were derived he immediately said they were non-human. M. Breuil was equally illogical and childish in his remarks about the sub-Crag scraper, because after having stated dogmatically that the specimen was 'natural' he was quite unable to state what natural force had produced the flaking to be seen upon it. These are the facts of the case, and no references to the curious remarks of Professor Boyd Dawkins, or the worthless flints collected by Professor Sollas on the beach at Selsey Bill, will alter them. I have been loath, especially at the present time, to write what I have done, but in view of M. Boule's provocative paper, which many people, not knowing the facts, will regard as reliable, I feel I am justified in speaking out, and in so doing to aid the cause of science.

J. Reid Moir.

12 St. Edmund's Road, Ipswich.

STUDIES IN EDRIOASTEROIDEA. A CORRECTION.

Sir,—I deeply regret to find that a bothering error has crept into the lettering of Text-figure 1, on p. 260,[1] illustrating Studies in Edrioasteroidea, VII. In each of the drawings the rays have been numbered in the wrong order, so that what are now V, IV, III, II, I should read I, II, III, IV, V. The numbers in the text itself, as well as in the figures on p. 398 are correct. Possessors of the Geological Magazine can perhaps make the necessary alteration without much difficulty. It will be put right in the complete set of reprints. With more than the usual apologies.

F. A. Bather.

September 17, 1915.

OBITUARY.

WILLIAM ANDERSON, F.R.S.E., F.G.S., F.R.S.G.S.

Born February, 1860. Died May 30, 1915.

Mr. W. Anderson was the eldest son of Dr. Joseph Anderson, late Keeper of the National Museum of Antiquities and Assistant Secretary of the Society of Antiquities of Scotland, Edinburgh.

A vacancy having occurred on the staff of the Geological Survey of New South Wales, Mr. William Anderson was recommended by Sir Archibald Geikie to Mr. C. S. Wilkinson, the Government Geologist, to fill the gap as Field Geologist. At the time of his selection he was a student at the University of Edinburgh, but proceeded forthwith to Sydney and commenced his official duties in September, 1886. Mr. Anderson's life on the Geological Survey was a very busy one; he contributed many valuable reports on the geological and mineral resources of the Colony, which may be found in the "Annual Reports of the Department of Mines of New South

[1] Geol. Mag., June, 1915.

Wales, 1886–91". Before leaving Scotland Anderson had already commenced to publish the result of local observations, at least two papers being read before the Geological Society of Edinburgh in 1885–6.

In 1888 he explored the Yarrangobilly Caves, which have since become a well-known tourists' resort; he also examined the neighbouring Kiandra Goldfield. During 1887 he accompanied Mr. Wilkinson to the Bingara Diamond-field and Cope's Creek, and reported on the possibility of existing auriferous deposits in the Byrock, Nyngan, and Girilambone Districts, and the well-established metalliferous zone around Cobar.

Pleistocene deposits, rich in marsupial remains, were known to exist at Myall Creek, near Bingara, and in 1888 Mr. Anderson was sent to investigate these and superintend the excavation of the fossils; these are now in the Mining and Geological Museum, Sydney. He also, during the year, reported on the important discovery of fish in the Hawksbury Formation at Talbragar, Mudgee District; these have since been described by Dr. A. Smith Woodward. In 1889 a most important investigation was commenced by the Geological Survey in the delineation of the great Cretaceo-Tertiary artesian water-bearing area of Western New South Wales, from the South Australian border to well beyond this side of the River Darling. This was entrusted to Mr. Anderson and carried on till 1891 (it was during this year we had the misfortune to lose our chief and friend Mr. C. S. Wilkinson). In 1890 he examined and reported on the Pambula and Cargo Goldfields; 1892 and 1893 were spent by Mr. Anderson in the survey of the Shoalhaven Valley, accompanied by Mr. P. T. Hammond as Field Assistant, but in June of the latter year he retired from the service and returned to Scotland.

Mr. Anderson's Official Reports are too numerous to mention in detail, but supplementary to these he contributed interesting articles to the Records of the Geological Survey of New South Wales. Prominent amongst these are: "Petrographical Notes on the Eruptive Rocks connected with the Silver-bearing Lodes at Sunny Corner," etc., "The Shell-heaps or Kitchen Middens" of our south-east coast; and in particular "The Occurrence of Opal in New South Wales".

No great lapse of time intervened between the termination of Anderson's Australian work and his appointment to the Geological Survey of India as Mining Specialist, but of this portion of his life I regret I am in possession of very few facts. He resigned his position in October, 1896.

We next hear of Mr. Anderson as Government Geologist of Natal, where he entered on his duties in January, 1899. It was not until the middle of 1901 that his first report on Natal and Zululand appeared. Between these dates the Lower Tugela District mapping was carried out, and a geological reconnaissance of the eastern half of Zululand. Two other very useful items are contained in this report, "Historical Sketch of Natal Geology" and "Bibliography of Natal and Zululand Geology, Part I". There is also a short paper by the writer: on "Fossil Plants from the St. Lucia Coalfield".

In June, 1900, Mr. Anderson acted as one of the examiners in Mineralogy and Geology at the Cape Town University.

His second report appeared in 1904 with a continuation of the Geology of Zululand and a "Report on the Stormberg Coal-measures to the West of Molteno" with Palæontological Reports by Messrs. Seward and Etheridge.

The third and final report appeared in 1907, embracing work accomplished 1903–5. Of this period upwards of seven months (1903–4) were spent in Europe on literary work. In the early part of 1903 he was a member of the Building Stones Commission, instituted by Lord Milner to investigate the distribution and quality of building stones of South Africa. This last report contains an important article on the "Cretaceous Rocks of Natal and Zululand"; another, the discovery in the latter territory of "Marine Fossiliferous Rocks of Tertiary Age containing Mammalian Remains"; and lastly the "Geology of the Drakensberg Mountains". A large portion of the volume is taken up with palæontological articles by Drs. R. Broom and A. S. Woodward, Professor W. B. Scott, Mr. G. E. Crick, and the writer. It is important to note the date of publication of this final report, as Mr. Anderson had already left the Natal Service, resigning his appointment in September, 1905.

After a brief interval he joined the well-known and wealthy firm of Eckstein & Co., mine-owners and financiers of Johannesburg, as mining adviser. In this capacity Anderson continued until some time in 1913, when from failing health he was advised to leave South Africa, and accordingly returned to his home in Edinburgh. During the period of his connexion with this firm there appeared his "Notes on the General Geology of the Waterberg District", etc., read before the Geological Society of South Africa in 1910, and previous to this a joint communication by Professor G. H. Stanley and himself on "The Intimate Relations between Archæology and Geology in South Africa", etc., was read before the same Society in 1909. The Edinburgh climate proved too severe after his long residence abroad, and acting on further advice he visited New South Wales, his first love, and took up his residence in Sydney, June, 1913. Mr. Anderson occupied his time in making occasional short geological excursions to the other States, one in particular to King Island, Bass' Strait. Here he investigated the sand-rock containing extinct marsupial remains. The result of his observations appeared in the Records of the Australian Museum, 1914.

At the beginning of the present year it became evident to his friends here that his health was rapidly declining, and after a very brief final illness he passed away on May 30 from cerebral hæmorrhage in his 56th year.

Mr. Anderson was a minute and accurate observer, a pertinacious man, of reserved demeanour except to a few of his most intimate acquaintances. To them he was of a genial disposition, possessed of a fund of quiet dry humour, and was a staunch and generous friend.

R. ETHERIDGE, JUN.

SYDNEY, NEW SOUTH WALES.
August, 1915.

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NOVEMBER, 1915.

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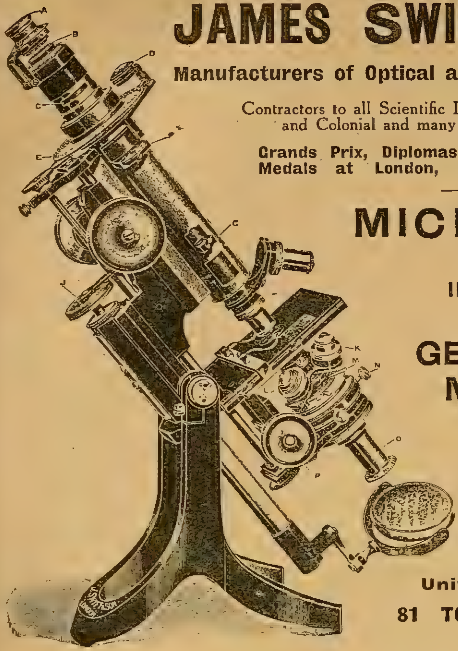

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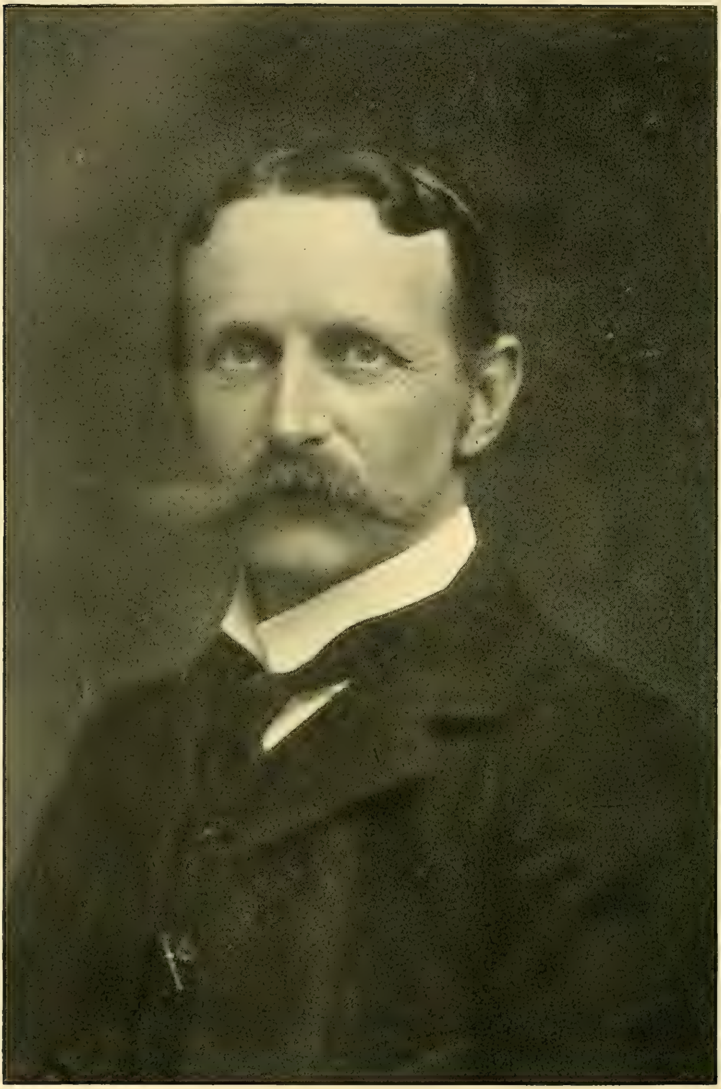

Sincerely Yours W. W. Watts

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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. XI.—NOVEMBER, 1915.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

William Whitehead Watts, LL.D., Sc.D., M.Sc., F.R.S., P. Pres.G.S., Professor of Geology in the Imperial College of Science and Technology, South Kensington; Hon. Fellow of Sidney Sussex College, Cambridge.

(WITH A PORTRAIT, PLATE XVI.)

WILLIAM WHITEHEAD WATTS was born at Broseley in Shropshire in 1860, and passed the critical part of his school life at Denstone. Here he came under the influence of the Rev. D. Edwardes, who taught him physics and chemistry, infected him with a love of science, and stimulated him to try for a scholarship at Cambridge. In spite of the winning of an exhibition, afterwards converted into a scholarship at Sidney Sussex College, supplemented by an exhibition from his old school, his maintenance at Cambridge was only accomplished by much self-sacrifice on the part of his parents.

By great good fortune it happened that J. F. Walker had that year been recalled to Sidney as Lecturer in Chemistry, and as young Watts kept in the rooms immediately beneath him the two soon became fast friends. Walker advised his pupil to dilute his study of chemistry with a little geology, and thus, by accident or design, gave him a chance to see that the subject was neither so dull nor so useless as he had previously supposed it to be. Work at the Woodwardian Museum under the stimulating teaching of Professors Hughes and Bonney, of Tawney and R. D. Roberts, coupled always with the friendly advice, assistance, and encouragement of Walker himself, soon made geology occupy the chief place in his time and thoughts, so that he adopted it for the final subject for his degree.

Another potent factor in the same direction was the foundation of the "Sedgwick Club" by a number of contemporaries, chief of whom were Middlemiss, Harker, and Tom Roberts, one of the few Cambridge clubs which has celebrated its 25th birthday and is now well on the way to its jubilee. It numbers most of the well-known Cambridge geologists among its members, and still meets for the discussion of papers and for excursions, among which those to Charnwood and Nuneaton have been conducted by one of the earliest presidents.

When, at the end of 1881, he had obtained a first class in Geology in the Natural Science Tripos, Watts was offered immediate work on the University Extension by R. D. Roberts, and left Cambridge to lecture to an audience of school-girls at Southport. He remained on the University Extension till 1891, lecturing on Physical Geography and Prehistoric Archæology, as well as on Geology and subjects closely related to it, at many towns in the north, west, and south-east of England as well as in the Midlands.

In 1882 Watts assisted J. E. Marr to fill the post of Professor Green during his absence from Leeds; in 1883–4 he acted as Deputy-Professor at the Mason College, Birmingham, during the illness of Professor Lapworth; and in 1888 as deputy at Oxford after the resignation of Professor Prestwich and before Professor Green was able to begin his work there. He also lectured during two bye-terms at Cambridge and obtained some experience of class-teaching at his old school, thus becoming acquainted with most sides of teaching work and with the methods and conditions of many men and institutions.

In 1891 the wander-period closed and Watts accepted an appointment on the staff of the Irish Geological Survey offered him by Sir Archibald Geikie. In addition to routine work he was specially charged with the care of the Survey Collections in the National Museum in Dublin, an unrivalled opportunity to become acquainted with the geology of the country. When this work was completed he was transferred to the English Survey, where he acted as petrographer in the room of Dr. Hatch until 1897.

In that year an assistant-professorship was founded to relieve Professor Lapworth of part of his routine work at the Mason College. Watts was selected for this post and for nine years had the privilege of assisting Lapworth in the teaching of geology and geography. In 1904 he was given a seat on the Senate and the title of Professor of Geography in the newly constituted University of Birmingham.

In 1906, on the resignation of Professor Judd from his chair at the Royal College of Science in London, the Crown appointed Watts to the vacant chair. Later the College was, with the Royal School of Mines and the Central Technical College, reconstituted as the Imperial College of Science and Technology and Watts was continued as Professor.

He was married in 1889 to Louisa Adelaide, the daughter of Colonel H. A. Atchison, who died in 1891, and in 1894 to Rachel, the widow of Arthur Turnour Atchison, Assistant Secretary to the British Association.

Watts' first original work was the outcome of a remark dropped by a geologist on seeing the Breidden Hills for the first time from the Wrekin, that they were "merely a mass of amygdaloïdal basalt". The fortunate discovery of andesitic tuffs and of fossils gave a clue to the age and succession of the rocks and resulted in a paper published by the Geological Society. Professor Lapworth determined the graptolites found and permitted Watts to share in many weeks of delightful field-work on the cognate igneous rocks of the neighbouring Shelve district, culminating in the discovery that the igneous masses were of laccolite or, as it would now be termed, phacolite form. After this work Lapworth passed down the sequence to Church Stretton and the Longmynd and Watts upward to the Silurian deposits of the Long Mountain, but the two came together on more than one occasion in general descriptions of the Shropshire and Birmingham districts, and in excursions of the British and Geologists' Associations to these regions.

On the Geological Survey, aside from descriptions of igneous and other rocks for the publication of maps, reports, and memoirs, Watts carried out three principal pieces of work. The first was the examination of the large suites of rocks collected by Jukes and others all over Ireland and deposited in the Survey Museum in Dublin. Very many types were discovered and briefly described in the Museum Guide, and the collections, with others specially made to supplement them, were arranged in the Museum.

On the English Survey Watts was associated with Mr. Lamplugh's work on the Crush-conglomerates of the Isle of Man, and joined with that geologist in his descriptions of them and of other igneous and metamorphic rocks in the island. He was also charged with the mapping and description of the ancient rocks of Charnwood Forest. He succeeded in supplementing existing knowledge on the succession of the rocks, their tectonic structure, and their place in the sequence; but the more interesting part of his work was to bring out the evidence that the region had stood out as a mountainous archipelago from the Carboniferous sea and the Permian and Trias lakes, and that the striking landscape of the district was a fossil landscape still preserving the features impressed upon it by the dry denudation and desert sandstorms of Triassic times.

As early as 1888 Watts had been struck by the importance of photographic records to the geologist, and he took up warmly the work initiated by O. W. Jeffs at the British Association at Bath. Eventually in 1895 he undertook the joint and afterwards the sole secretaryship of the Geological Photographs Committee, and issued eleven reports on the photographs thus brought together and stored at the Museum of Practical Geology. The quality of geological photography steadily improved, and in 1900 the Committee decided on the publication of sets of prints and slides of typical geological photographs accompanied by descriptions by authorities on the subjects represented. Watts acted as editor and publisher of the series which was completed in 1904, and met with great success. Now "British Geological Photographs" form the basis of teaching-sets all over the world.

In 1886 Watts became one of the secretaries of Section C of the British Association, in association with W. Topley, whom he succeeded as recorder in 1889. This office he held until 1894, a most valuable experience which brought him into friendly relations with many of the leading English and Foreign geologists.

He became Chairman of the Conference of Delegates in 1902, and President of Section C in 1903 at Southport, when his address was devoted to geological education and its value to the community.

It was in 1898 that he undertook the duties, including the abstracting of papers, of Secretary of the Geological Society, and remained in that office till 1909. The chief event of this period was the celebration of the centenary of the Society in 1907, for which he undertook a considerable share of the organization, and in 1909 published the official account. In 1910 he was elected President of the Society and delivered two addresses, the first dealing with geology as an evolutionary science, the second with the problem of coal supply. His period of office was also marked by the transfer of the Society's collections to the Museums of Natural History and Practical Geology, and the consequent extension of the Library.

As President of the Geologists' Association during its Jubilee (1908) and the following year, Watts delivered two addresses dealing with the history and the work of the Association. He was also present when this body visited the Paris Basin under the genial guidance of M. Dollfus.

Watts had the good fortune to be at Birmingham during the growth of the Mason College into Birmingham University; at South Kensington when the School of Mines developed into the Imperial College; and in London during the recent expansion of its University, acting part of the time as Chairman of the Board of Studies in Geology and later as Dean of the Faculty of Science, and sitting on the Senate and the Academic Council. He was further fortunate in fitting into the admirable teaching scheme of Lapworth at Birmingham, and in succeeding to the eminently practical methods of Judd. The experiences thus gained, coupled with the training of the University Extension, at a school, and at other Universities, has naturally reacted on his own teaching and intensified its practical and economic sides. This is illustrated by his book *Geology for Beginners*, 1898, but the chief outcome has been the establishment at the Imperial College of a Chair of Economic Mineralogy, occupied by C. G. Cullis, the initiation of a school of Oil Technology, and the bringing of the teaching into close relations with the other technological work of the Imperial College.

Professor Watts has served on the Councils of many Scientific Societies, the Royal, Geological, Geographical, Mineralogical, and Palæontographical, as well as the Geologists' and British Associations. He served on the Funafuti Committee of the Royal Society and had much to do with the organization of the Reef-drilling expedition; while as a member of the Education Committee of Sutton Coldfield he superintended the erection and equipment of the technical school there. He has acted as examiner in Geology to the Universities of Oxford, Cambridge, London, Durham, Leeds, Wales, Ireland, and New Zealand, and in Geography at Cambridge and London. He has been Secretary and President of the Vesey Club, and President of the Sutton Scientific Society, the Geographical Section of the Birmingham Natural History Society, and the Birmingham Naturalists' Union.

He joined the Geological Society in 1882, received the Wollaston Fund in 1895, and the Murchison Medal in 1915. The official degree of M.Sc. was conferred on him at Birmingham in 1902, that of Sc.D. at Cambridge in 1908, and the honorary degree of LL.D. as the representative of the Geological Society at the Tercentenary gathering at St. Andrews in 1911. He became a Fellow of the Royal Society in 1904, was elected to a Fellowship at Sidney Sussex College in 1888, and was made an Honorary Fellow of his old College in 1910.

List of Titles of Papers by Professor W. W. Watts, LL.D., Sc.D., F.R.S.

1883. "The Geology of Lilleshall Hill and its Vicinity": Trans. N. Staffs Field Club, vol. xvii, pp. 45–7.
1885. "On the Igneous and Associated Rocks of the Breidden Hills in East Montgomeryshire and West Shropshire": Quart. Journ. Geol. Soc., vol. xli, pp. 532–46; Powysland Club, Collections Hist. and Arch., vol. xxiv, pp. 107–28.
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1887. "A Shropshire Picrite": Rep. Brit. Assoc., 1887, p. 700.
1888. "Preshevalsky's Horse" Nature.
"Outcrops": Geol. Mag., Dec. III, Vol. V, pp. 356–8.
"An Igneous Succession in Shropshire": Rep. Brit. Assoc., 1888, p. 685.
1889. (With W. Whitaker) "List of Works on the Geology, Mineralogy, and Palæontology of Shropshire": Trans. Shropshire Arch. Soc., vol. xii, pp. 33–62.
1890. "The Geology of the Long Mountain": Rep. Brit. Assoc., 1890, p. 817.
1892. "On some Limerick Traps": Rep. Brit. Assoc., 1892, p. 727.
1893. "Notes on the Occurrence of Perlitic Cracks in Quartz": Rep. Brit. Assoc., 1893, p. 781; Quart. Journ. Geol. Soc., vol. L, pp. 367–76, 1894.
"Notes on a Hornblende Pikrite from Greystones, Co. Wicklow": Rep. Brit. Assoc., p. 767.
1894. (With Professor C. Lapworth) "The Geology of South Shropshire": Proc. Geol. Assoc., vol. xiii, pp. 297–355.
(With R. S. Herries) "[Account of the] Excursion to the County of Shropshire": Proc. Geol. Assoc., vol. xiii, pp. 381–7.
"On a Keuper Sandstone cemented by Barium Sulphate, from the Peakstones Rock, Alton, Staffordshire": Rep. Brit. Assoc., 1894, p. 665.
"Appendix on some Boulders collected by Mr. Cameron [Catworth, Huntingdon]": Proc. Geol. Assoc., vol. xiii, pp. 359–60.
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1895. (With A. McHenry) "Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland": Geol. Surv. Ireland, 1895, pp. 1–155.
(With G. W. Lamplugh) "The Crush-Conglomerates of the Isle of Man": Quart. Journ. Geol. Soc., vol. li, pp. 563–97.
(With W. Gunn and C. T. Clough) "[Petrological Notes on] the Geology of Part of Northumberland": Mem. Geol. Surv., Quarter-sheet 110 S.W., new series 3, *passim*.
(With J. D. Paul) "Rocks collected in the Puddle Trench, Brazil Wood, near Mount Sorrel": Trans. Leicester Lit. and Phil. Soc., vol. iv, p. 12.
"Notes on some Tarns near Snowdon": Rep. Brit. Assoc., 1895, p. 683.
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II.—Suggestions for a Revised Classification of Trilobites.

By H. H. Swinnerton, D.Sc., F.G.S., F.Z.S., Professor of Geology, University College, Nottingham.

Introduction.

In 1897 C. E. Beecher[1] published his "Outline of a Natural Classification of the Trilobites", which has since "proved superior to any previously proposed". Nearly a score of years have passed since that time and many new Trilobites have been discovered, the majority of which fit into this system without difficulty and prove that to a large extent it is conceived on a sound basis. A few, however, do not fit in and have therefore revealed in it weaknesses, the existence of which tend to hinder the systematic study of Trilobites. In the following pages it is proposed to point out these weaknesses and to make suggestions for modifying and extending Beecher's system upon what it is hoped will prove to be natural lines.

On the whole the families given by Raymond in the 1913 edition of Zittel's *Textbook of Palæontology* as edited by Eastman will be used as the basis for this discussion.

Recent Classifications.

Beecher's classification has been adopted without modification of its broad lines by English and American, but not by all Continental writers. Among the latter Gurich[2] and Jaekel[3] have recently suggested systems which differ materially from Beecher's.

[1] *Amer. Journ. Sci.*, vol. iii, 1897.
[2] *Centralblatt Min. Geol. Palaeont.*, 1907, p. 129.
[3] Zeitsch. Deutsch. geol. Ges., Bd. lxi, p. 380, 1909.

That of Gurich is as follows :—

Order TRILOBITA.
Series *Oligomeria* :—With few free trunk segments.
Sub-order 1. *Isopygia.* Pygidium about the same size as the cephalon.
Agnostidæ, Microdiscidæ.
Sub-order 2. *Heteropygia.* Pygidium distinctly smaller than the cephalon.
Trinucleidæ, Ampycinæ, Dionidæ, Æglinæ.
Series *Pliomeria* :—With many free trunk segments.
Sub-order 3. *Micropygia.* Pygidium very small.
Olenellidæ, Paradoxidæ, Remopleuridæ, Ellipsocephalidæ, Harpedidæ, Olenidæ, Arethusinidæ, Cyphaspidæ.
Sub-order 4. *Macropygia.* Pygidium large, often equal to the cephalon.
Group *a.* Opisthoparia.
Proetidæ, Dicellocephalidæ, Lichidæ, Acidaspidæ, Bronteidæ, Asaphidæ.
Group *b.* Gonatoparia. Suture cuts genal angle.
Homalonotidæ, Calymmenidæ.
Group *c.* Proparia.
Phacopidæ, Cheiruridæ, Encrinuridæ.

Jaekel, after a careful study of the Agnostidæ, considers that these Trilobites are sufficiently distinct from all others to be placed in a separate division equal in value to that containing all other Trilobites. He therefore proposes the name Miomera for those which, like Agnostidæ and Microdiscidæ, have only three trunk segments, and Polymera for all with six or more free segments.

Beecher's Classification.

The developmental details upon which Beecher's classification is based are too well known to justify recapitulation here. It will suffice to recall the facts that in the earliest larval stages of both opisthoparian and proparian Trilobites the free cheeks are not seen on the dorsal side, but that, as development advances, the facial suture appears first of all close to the margin and then moves towards the glabella, so that the free cheek, at first narrow, broadens out. It is therefore assumed—whether rightly or wrongly the future will decide—that in the earliest stages the free cheeks are on the ventral side and that the sutures run either along or below the margin. It is further assumed that the occurrence of this hypothetical phase in so many widely separated Trilobites is due to there having been a corresponding stage in the evolution of both the Opisthoparia and the Proparia. This leads naturally to the supposition that this hypoparian condition might have been retained into adult life by some known Trilobites, hence the creation of the division Hypoparia. Whilst the divisions Opisthoparia and Proparia are almost above reproach the same cannot be said of the division Hypoparia.[1] Even Gurich to some extent recognizes the two former, but rejects the latter.

The Hypoparia.

In the English edition of Zittel's textbook the following families are placed under the order Hypoparia: Agnostidæ, Eodiscidæ (Microdiscidæ), Shumardiidæ, Harpedidæ, Trinucleidæ, Raphiophoridæ.

[1] Cf. H. Woods, Cambridge Natural History, vol. Crustacea, ch. Trilobites, pp. 226, 244.

According to the definition of the last-named family there are "small free cheeks visible upon the dorsal surface".[1] If figures are to be trusted the members of this family are as typically opisthoparian as are *Conocoryphe* and *Atops*. Presumably they are placed here because of their evident relationship to the Trinucleidæ.

Among the Trinucleidæ two lines have been described as facial sutures, one which has only occasionally been found and which pursued the course of an advanced opisthoparian type, viz. across the cheek from the anterior of the glabella to the posterior margin. The other ran along the margin of the cephalon. Barrande discussed the relative merits of the two lines, and concluded that the former was only an ornamental nervure and that the latter was the true suture. During recent years evidence has accumulated which shows that Barrande[2] was in error.

The first piece of evidence is negative and suggestive rather than conclusive. If the marginal line be the facial suture, then the dorsal portion of the broad marginal limb belongs to the fixed cheek and the ventral to the free cheek. Numerous pits with connecting pores pass through this limb from the upper to the under surface. These might be expected to show traces of the separation between the free and the fixed cheek regions. According to Reed,[3] "the hour-glass shaped hollow pillars representing the opposite and communicating pits in the upper and under surfaces are continuous and show no transverse plane of fission." It is of course conceivable that secondary fusion has taken place, but why should there be fusion in the walls of the pits and not along the edge of the cephalon?

The genus *Orometopus*, which possesses well-formed compound eyes and a clearly marked suture of an advanced opisthoparian type, supplies positive and conclusive evidence. This may be best stated in the words of Lake[4]: *Orometopus* "is the earliest genus of the Trinucleidæ and must therefore be looked upon as the primitive form; and the conclusion is inevitable that in the later genera the absence of compound eyes and supposed marginal position of facial sutures are degenerative characters. It is indeed no longer improbable that the ocelli which occur in the middle of the cheeks in some species of *Trinucleus* and *Ampyx* may represent normal eyes, and that the lines which Salter and M'Coy observed running from these ocelli to the margins may be fused facial sutures as they supposed. If this be so the Trinucleidæ can scarcely be included in Beecher's Hypoparia".

Dollo[5] regards *Trinucleus* as a Trilobite adapted for a life spent permanently in the mud. If this was its mode of life it is easy to understand the reduction of the compound eye to such a simple one as that of *Tretaspis* or of the young *Trinucleus*. The loss of the facial suture by the fusion of free with fixed cheeks would produce a more rigid head-shield like that of other Trilobites said to have had a burrowing habit such as *Olenellus* and other Mesonacidæ. The

[1] *Textbook of Palæontology*, Zittel, ed. Eastman, vol. i, p. 713, 1913.
[2] J. Barrande, *Système Silurien*, Trilobites, p. 616.
[3] Geol. Mag., 1912, p. 347.
[4] Monogr. Palæont. Soc., 1907, p. 45.
[5] *La Paléontologie Ethologique*, Bruxelles, 1910, p. 417.

absence of a facial suture in members of this last-named family is not regarded as barring them from admission to the Opisthoparia, or as justifying their reference to the Hypoparia.

The facts given above together with the evident relationship of *Dionide*[1] to the Trinucleidæ on the one hand and to the Harpedidæ on the other creates a strong presumption in favour of the view that the ocelli of the latter are not of different origin from but are vestiges of compound eyes.[2] If this be so they may mark the position of an opisthoparian type of facial suture which has disappeared under similar influences to those which have acted on *Trinucleus*.[3]

Lake,[4] discussing the systematic position of *Shumardia*, says: "The genus *Shumardia* has by some writers been placed in the family Agnostidæ. Moberg, however, in 1890 pointed out that it presents scarcely any resemblance to *Agnostus*, except in the absence of eyes and facial sutures, and he concluded that it belongs rather to the Olenidæ. At a later date Pompeckj considered it to be most closely related to *Conocoryphe*, while Reed, like Moberg, included it in the Olenidæ." Allowing for the absence of eyes and sutures *Shumardia* resembles *Ellipsocephalus*[5] much more closely than it resembles either *Agnostus*, *Olenus*, or *Conocoryphe*. This comparison is analogous to that of *Trinucleus* with *Orometopus*. The difference in time of appearance of *Shumardia* and *Ellipsocephalus*, however, makes one hesitate to place them near together.

In discussing the Agnostidæ Beecher claims to have found "under favourable conditions of preservation" a distinct plate separated by a suture which "can be compared only with free cheeks".[6] So far as literature is known to me this is the only case in which Beecher actually saw hypoparian free cheeks. It is interesting to note, therefore, that Jaekel,[7] whose material seems to have been exceptionally good, definitely states that sutures are absent. From the fact that some workers seem to have found vestiges of eyes on the cheeks he expresses the opinion that the Agnostidæ are forms in which the eyes have degenerated and the free cheeks have fused with the fixed cheeks. He shows,[8] moreover, that the habit these Trilobites had of shutting themselves up with the edge of the pygidium fitted closely against that of the cephalon necessitates absence of eyes and, correlatively, of facial sutures on the ventral side.

[1] F. R. C. Reed, Geol. Mag., 1912, p. 202.

[2] Cf. F. R. C. Reed, Geol. Mag., 1898, p. 446 et seqq.

[3] Some time after this paper was finished Mr. H. H. Thomas kindly called my attention to an article on *Harpes*, by Rudolf Richter, in the *Zoologischer Anzeiger* for December, 1914, a copy of which had reached England. This author has made a very careful study of the minute structure of this genus. He shows that the 'eyespots' consist of biconvex lenses like those of the normal Trilobite eye, and he regards them as vestiges of a once well-developed compound eye. He also shows that the marginal suture cannot be regarded as homologous with the true facial suture.

[4] Monogr. Palæont. Soc., 1907, p. 40.

[5] *Vide infra.*

[6] *Amer. Journ. Sci.*, 1897, p. 183.

[7] Op. cit., p. 387; *vide* also Woods, op. cit., p. 225.

[8] Op. cit., p. 388.

Walcott[1] places his new genus *Mollisonia* near the Agnostidæ, and in describing it refers to indications of eyes and facial sutures on the dorsal side. The course of the sutures is not quite clear either from descriptions or figures, but they seem to conform to the proparian type. The presence of seven free segments gives the deathblow to Jaekel's[2] suggested divisions Miomera and Polymera. At the same time it supplies strong support for his view[3] that the Agnostidæ are highly specialized Trilobites. This specialization in so many respects supplies further support for the hypothesis that their blindness is not primitive, and that the absence of facial sutures is due to fusion and not to the submarginal position of the cheeks.

While the orders Opisthoparia and Proparia correspond to facts easily and clearly observed in nature the same cannot be said of the order Hypoparia. The existence of a hypoparian stage in development and in evolution is open to question. Beecher himself does not seem ever to have actually seen free cheeks on the under side either in young or adult forms except in the doubtful instance of the Agnostidæ. In fact, there seems to be no case known of an adult Trilobite which is undoubtedly hypoparian.

As already seen, Beecher based his conception of a hypoparian stage in evolution largely upon the development of both opisthoparian and proparian forms. He did not, however, give adequate consideration to either the development or the adult structure of that most primitive of all Trilobite families, the Mesonacidæ. Before considering them it is necessary to emphasize the importance and value of one of Beecher's[4] fundamental conceptions, viz. that in the Trilobite organization the facial sutures[5] when present are essentially associated with the eye. Even if the presence of a visual area be denied[6] this conception is still true for the eye-lobe or the homologue of the palpebral lobe.

When Walcott[7] instituted the family Mesonacidæ he described it as being distinguished from the Paradoxidæ by the absence of facial sutures. Beecher[8] states that in *Olenellus* and *Holmia* "false sutures are recognized" which are "evidently real sutures in a condition of symphysis, which often occurs in *Phacops*", etc. This explanation —loss by fusion—was the only one open to him since he believed that even in the earliest stages of evolution sutures were present. Some years later Walcott[9] in discussing the sutures of the family says, "facial sutures are rarely represented even by elevated lines on the exterior surface or depressed lines on the interior surface of the cephalon." He also in defining the family afresh says "facial

[1] Smithsonian Miscellaneous Collections, vol. lvii, p. 195, 1912.

[2] *Vide supra.*

[3] Op. cit., p. 392.

[4] Op. cit., pp. 100, 191.

[5] Cf. J. Barrande, op. cit., pp. 615, 616. Barrande decided that this association of sutures with eyes was not essential. He based his view especially upon the existence of a marginal suture in *Trinucleus*.

[6] Woods, op. cit., p. 233.

[7] Tenth Ann. Rep. U.S.G.S., 1891, p. 635.

[8] Op. cit., p. 191.

[9] Smiths. Misc. Coll., vol. liii, p. 242, 1910.

sutures rudimentary or in a state of synthesis".[1] The rest of his monograph leaves it uncertain as to whether or not he is really using the word rudimentary as opposed to vestigial and synthesis as opposed to symphysis. If the definition be taken at its face value he is evidently leaning towards the point of view of the present writer, viz. that the facial sutures were not necessarily present in primaeval Trilobites and that the Mesonacidæ exhibit the Trilobite organization just when these lines are coming into being. The genus *Nevadia*[2] (Fig. 2*a*), which is one of, if not the most primitive of undoubted Trilobites, and which should therefore approximate to Beecher's hypoparian archetype, has no definitely established facial sutures, and its eyes, like those of all other Mesonacidæ, are situated on the dorsal side far from the margin of the cephalon and close to the glabella—that is to say, it is the reverse of hypoparian in every respect.

Not less decisive is the evidence supplied by the development of the Mesonacidæ. Beecher[3] infers that, because the eye travels over the margin on to the dorsal side during the development of the types he considers, therefore the free cheeks must be wholly ventral. The earliest known stages in the development of *Olenellus* (*Elliptocephalus*) *asaphoides*[4] are quite as early as any of those referred to by Beecher in other types, nevertheless from the very outset the rudiments of the eyes are dorsally situated and are well within the margin of the head-shield. This fact implies that if facial sutures had been present the free cheeks would have been upon the dorsal side. Facial sutures, however, are not present, even though the embryo is so primitive that, unlike any known embryo outside this family, it shows the pleural elements of the fixed cheek region quite distinctly. According to Bernard[5] the facial suture is formed in Trilobites generally along the line which separates the first and second pleuræ.

Walcott[6] has described a new Crustacean genus *Marella* in which he says "the trilobite is foreshadowed". Though so beautifully preserved that even minute details in the structure of the appendages may be discerned there is no mention in his description nor indications in his plates of a facial suture.

Along with *Marella* Walcott[7] also described a primitive Trilobite, *Nathorstia transitans*, which, whilst it is "essentially a Trilobite", yet exhibits characters which link it to the Branchiopods and Merostomes. The position of the eyes and the absence of facial sutures in this genus also bear out the conclusions already indicated above that there was no such stage as the hypoparian in the evolution of Trilobites as a whole. On the contrary, the earliest trilobitic organisms had no facial suture. The Branchiopods and the Merostomes approach more closely to these than do any other animals. In the former there are no traces of sutures. In some of the latter

[1] Smiths. Misc. Coll., vol. liii, p. 236, 1910.
[2] Ibid., p. 257.
[3] Op. cit., p. 100.
[4] Ford, *Amer. Journ. Sci.*, 1877, 1881; Walcott, op. cit., 1891, pl. lxxxviii; Bull. U.S.G.S., No. 30, pl. xvii, 1886.
[5] Q.J.G.S., 1894, p. 419.
[6] Op. cit., 1912, p. 192.
[7] Op. cit., p. 194.

a posterior facial suture such as has been seen apparently in some Mesonacidæ is present, but no well-established and clearly defined line such as characterizes the majority of Trilobites occurs.

For the reception of Trilobites and Trilobite-like organisms in which the absence of facial sutures is primary the Order PROTOPARIA may be instituted. From this protoparian stock there arose independently, as will be seen, several widely different types with free cheeks. The position in which the suture appeared in the earliest representatives of each of these types depended upon the position of the eye, whether it was near the glabella, or near the margin, or, conceivably in some cases, on the ventral side.

THE INTERRELATIONSHIPS OF THE PRO- AND OPISTHOPARIA.

The predominance of Opisthoparia in the Cambrian and of the Proparia in later rocks suggests that the latter descended from the former. This is apparently supported by the existence of the families Calymmenidæ and Homalonotidæ, in which the suture cuts the margin at the genal angle and thus seems to furnish a transition from one to the other.

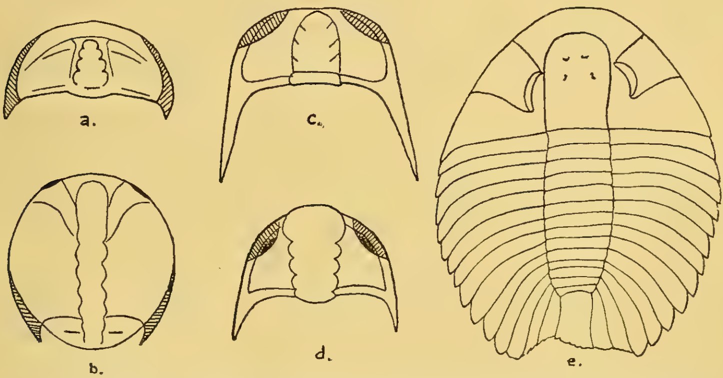

FIG. 1.—Diagrams to illustrate differences in mode of origin of free cheeks of Opisthoparia and Proparia. *a.* Head-shield of *Conocoryphe* (from Beecher); *b.* metaprotaspis of *Ptychoparia kingi* (from Beecher, *Amer. Geol.*, 1895, p. 171); *c.* head-shield of *Anacheirurus* (*Cheirurus*) *frederici* (reconstructed after Salter, Mon. Pal. Soc., pl. v, fig. 18); *d.* head-shield of young *Dalmanites* (from Beecher); *e. Burlingia* (after Walcott).

The discovery of *Burlingia*[1] (Fig. 1*e*) as early as the Middle Cambrian throws doubt on this view of the interrelationships of the two orders. This form is in many respects as primitive as the Mesonacidæ and yet is as typically proparian as the most specialized of the Cheiruridæ. On the other hand, the families Calymmenidæ and Homalonotidæ do not appear before the Tremadocian.

If Proparia descended from Opisthoparia evidence should be forthcoming from their development. But such evidence is altogether lacking. The development of the free cheek follows quite different

[1] C. D. Walcott, Smiths. Misc. Coll., vol. liii, p. 14, 1908.

lines in the two orders (Figs. 1*b*, *d*). In Opisthoparia the suture becomes visible for the first time at the *postero-lateral* margin of the head-shield; in Proparia, on the contrary, it appears at the *antero-lateral* margin. This difference is exhibited in adult life also by the lowliest members of the two orders; compare, for example, *Conocoryphe* and *Anacheirurus* (Figs. 1*a*, *c*). The opisthoparian and proparian conditions are therefore differentially or mutually exclusive and have arisen independently. As will be shown later, this conclusion receives confirmation from the existence of evidence that the opisthoparian condition has been evolved independently at least twice within the limits of the order Opisthoparia.

The Calymmenidæ and Homalonotidæ.

As long ago as 1898 Pompeckj[1] traced the descent of the Calymmenidæ through *Pharostoma* to *Bavarilla*; *Pharostoma* has narrow marginal cheeks of the opisthoparian type and *Bavarilla* is one of the Olenidæ.[2] He likewise traced the Homalonotidæ back to the olenid genus *Neseuretus*. In other Olenidæ,[2] e.g. *Triarthrus*, the facial suture cuts the margin at the genal angle. It is evident, therefore, that among some of the olenid Opisthoparia one tendency of specialization is the shifting of the post-ocular facial suture towards the genal angle. This tendency develops most rapidly in, and becomes the dominant peculiarity of, the Calymmenidæ and the Homalonotidæ.

Gurich grasped the importance of this peculiarity and formed a group, the Gonatoparia, to include those families which show it. This group has not the same taxonomic value as the two orders; it might, however, be regarded as a section, the Calymmenina, of that large and unwieldy assemblage the Opisthoparia.

The error in Gurich's Classification.

A glance at a system of classification should reveal first the main lines of descent and after that the progressive stages along each of those lines. For defining lines of descent differential characters are the most reliable, hence the solidity of two of Beecher's orders. The foundation mistake made by Gurich is that his main divisions are based upon progressive characters, viz. differences in the number of free segments and in the size of the pygidium. Beecher's order Hypoparia exhibits the same weakness. The institution of an order Protoparia is open to the same criticism.

It is beyond question that the earliest ancestors of the Trilobites and indeed of all Arthropods possessed an annelidan type of segmentation.[3] In all Arthropods this has been masked in the anterior part of the body by the fusion of segments. This process of cephalization reaches its acme in the crab-like Crustacea. It is characteristic of the Trilobite organization that it also exhibits a strong tendency for a similar fusion to take place at the posterior end of the body. Gurich emphasizes the importance of this tendency by unconsciously

[1] *Neues Jahrb.*, 1898, p. 187.
[2] Strictly that portion of Olenidæ relegated later to the Ptychoparidæ.
[3] Cf. H. M. Bernard, Q.J.G.S., 1894, 1895.

making it the basis of his classification, and the names of some of his sub-orders may be usefully adapted for describing the stages in this process of caudalization.

The earliest and most primitive stage is one in which the pygidium consists of a telson or of a telson plus only two or three segments—this may be called the *micropygous* stage. This passes into the *heteropygous* stage, in which the pygidium includes a greater number of segments, but is distinctly smaller than the cephalon. In the final or *isopygous* stage the pygidium is approximately equal to or even larger than the cephalon.

Some or all of these stages may be represented in any genetic series of Trilobites. The use of the number of free segments and the size of the pygidium as the definitive characters of orders or sub-orders results in the bringing together of forms which belong to quite different lines of descent, e.g. Asaphidæ and Phacopidæ,[1] and separates others which are closely allied, e.g. Arethusinidæ and Proetidæ.[1]

Suggested Subdivision of the Opisthoparia.

The order Opisthoparia now contains such a great number of families that some division into sub-orders is rendered necessary. One distinct section, the Calymmenina, has been already recognized (p. 494). The remaining families must now be studied with a view to detecting, if possible, other equally natural groups within this order.

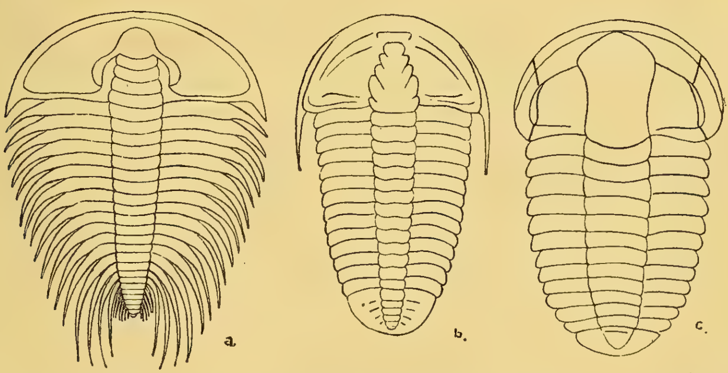

Fig. 2.—Types of Lower Cambrian Trilobites. *a. Nevadia* (after Walcott, 1910, pl. xxiii); *b. Conocoryphe* (*Conocephalites*) *sulzeri* (after Bronn, Klass, Ord., Bd. v, Arthropods, pl. xlv); *c. Ellipsocephalus* (after Barrande).

Already in the Lower Cambrian the genera *Nevadia*,[2] *Conocoryphe*,[3] and *Ellipsocephalus* exhibit distinct types. Though in one or two respects each is specialized, in the general sum of their characters they are each more primitive than any other allied genera.

[1] *Vide* p. 488.
[2] C. D. Walcott, Smiths. Misc. Coll., vol. liii, p. 256, 1910.
[3] *Conocephalites sulzeri*, Schlot.

In the head-shield of *Nevadia* the glabella diminishes anteriorly, and is divided by complete transverse furrows into five segments, of which the first is longer than the others, and sends off lateral stout eye-lobes which probably bear a visual area[1] externally and distally. In *Conocoryphe* the glabella is almost equally primitive, but its anterior segment is small and its furrows oblique and not continuous across. The absence of eyes is probably secondary.[2] In *Ellipsocephalus* the glabella has already attained a high degree of specialization, for it is quadrate in outline and may have all its furrows smoothed away. It possesses eyelines and elongated eyes, both of which are primitive characters.

In *Nevadia* there is no facial suture, but its potential position (Figs. 2*a* and 3*a*) is marked by the eye. From this it will be seen that the free cheek region of *Nevadia* is of great breadth, whilst the fixed cheek is particularly narrow. In *Conocoryphe* (Fig. 2*b*) and *Ellipsocephalus* (Fig. 2*c*) these relative proportions are reversed, for the free cheek is narrow and marginal whilst the fixed cheek is broad.

The fixed cheek largely represents the pleural portions of the hind segments of the glabella. Its insignificance in the one genus and its great size in the other genera accord with the morphological characteristics of the trunk segments.

Bernard[3] considers that in the evolution of Arthropods from an annelid ancestor pleuræ appeared first on the head segments, and that the early Arachnids and Trilobites specialized by "the continuation of the original head pleuræ along the whole length of the body". In *Nevadia* (Fig. 2*a*) this specialization has not advanced so far as in *Conocoryphe* and *Ellipsocephalus*. Leaving the pleural spine out of account the pleural lobes of the first few trunk segments of *Nevadia* are not so imposing as in the other two genera. They then diminish in size posteriorly and finally disappear, so that the hinder segments consist of axis only. In other genera (Figs. 2*b*, *c*) the pleural lobes are well developed even in the pygidium.

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

III.—On some new Uniserial Cretaceous Cheilostome Polyzoa.

By W. D. Lang, M.A., F.G.S.

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(PLATE XVII.)

I. Rhammatopora,[4] new genus.

In 1890 Vine described *Membranipora gaultina*,[5] a uniserial Cheilostome from the Cambridge Gault. A peculiarity of this species was 'a puckering' or 'folding-in of the wall below the area'

[1] *Vide* Walcott on *Olenellus gilberti*, in Smiths. Misc. Coll., vol. liii, p. 327, 1910. The discovery of the presence of a visual area in *Olenellus gilberti* is against Wood's suggestion (op. cit., p. 232) that the eye-like lobe of *Olenellus* "is really of the nature of a pleura".

[2] *Nevadia*, *Burlingia*, *Marella*, *Nathorstia*, are all more primitive than *Conocoryphe*, and yet they all possess well-formed eyes. Again, secondary loss of eyes is now definitely established in some families, e.g. Trinucleidæ.

[3] Q.J.G.S., 1895, p. 359.

[4] τό ῥάμμα, 'a seam.'

[5] Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, pp. 484, 461.

shown by Vine in his figure of the type-specimen.[1] Unfortunately this specimen cannot be found; but a well-preserved paratype specimen (from the same horizon and locality) exhibits the same structure and shows that this is due to the collapse of the extra-terminal front wall along a median line proximal to the aperture. Other zoœcia of the same specimen show the extra-terminal front wall entire and a thin median seam—or *rhamma*—running proximally from the aperture. The rhamma appears in some instances as a ridge and in others as a depression; in some zoœcia it is not apparent; and when visible is extremely fine. In many cases the front wall is broken along it (as in Vine's figure) and thus the rhamma probably indicates a line of weakness. It is suggested that the rhamma is a ridge bounded by two furrows and that the front wall is thicker at the ridge and thinner in the furrows. The rhamma, then, would easily be broken off, and in such specimens a depression would appear in its place; and a thin groove on each side would constitute a general line of weakness which would account for the frequent breaking down of the front wall. Owing to the extreme fineness of the structure it cannot be definitely stated that that is the case. Vine further records *Membranipora gaultina* from the Red Chalk of Hunstanton[2] and from the Chalk Marl of Cambridge.[3] Specimens of the former horizon only are in his collection, but similar forms from the latter horizon have been obtained by washing by the late Mr. F. Möckler and are in the British Museum. In each case the rhamma is shown, though the specimens show differences from each other and from the Gault form. Finally Mantell[4] figures and describes from the Lower Greensand a uniserial Cheilostome possessing a rhamma and obviously related to the Albian and Cenomanian forms. These then may be grouped in a new genus *Rhammatopora*, with the following diagnosis.

Diagnosis. Incrusting, uniserial, Cheilostome Polyzoa with bilateral branching;[5] zoœcia monomorphic, divided into a proximal caudal and distal capitular portion; termen[5] beaded; extra-terminal front wall[5] well developed proximally and provided with a median seam or rhamma which also appears to mark a line of weakness since the extra-terminal front wall is often crushed in along this line; intra-terminal front wall[5] represented by a narrow bevel, tending to become broader proximally.

Genotype. *Membranipora gaultina*, Vine.

Distribution in time. Aptian to Cenomanian.

Remarks. Of the three genera into which the species of *Rhammatopora* have been placed by various authors, *Crisia* is a Cyclostome Polyzoan, *Membranipora* is multiserial and *Hippothoa* has a completely calcareous intra-terminal front wall; none possesses a rhamma.

[1] Vine, 1892, Proc. Yorks. Geol. Poly. Soc., new series, vol. xii, part 2, pl. vi, fig. 15.
[2] Vine, 1890, *loc. cit.*
[3] Vine, 1890, *op. cit.*, p. 461.
[4] Mantell, 1844, "Medals of Creation," p. 285, pl. lxiv, figs. 3, 10, 10*b*.
[5] For these terms, see Lang, 1914, Geol. Mag., Dec. VI, Vol. I, p. 6.

Key to the genus *Rhammatopora.*

A. Zoœcia tapering somewhat distally as well as proximally; proximal end of capitulum bounded by well-curved lines
1. *R. johnstoniana* (Mantell).

B. Zoœcia blunt distally and tapering proximally.
1. Outline of proximal end of capitulum bounded by hardly-curved lines; aperture elliptical. 2. *R. vinei*, n.sp.
2. Outline of proximal end of capitulum bounded by well-curved lines.
a. Extra-terminal front wall small laterally; aperture oval to ovate . . . 3. *R. gaultina* (Vine).
b. Extra-terminal front wall well-developed laterally; aperture ovate to elliptical . 4. *R. pembrokiae*, n.sp.

Rhammatopora johnstoniana (Mantell).

Synonymy.

Crisia Johnstoniana; Mantell, 1844, "Medals of Creation," 1st edition, p. 285, pl. lxiv, figs. 3, 10, and 10*b*; and 1854, *op. cit.*, 2nd edition, p. 269, pl. lxxxix, figs. 3, 10, 10*b*.

non Hippothoa Johnstoni (Mant.); Morris, 1854, "A Catalogue of British Fossils," 2nd edition, p. 125; Upper Chalk; Kent, Sussex. [? = *Herpetopora anglica*].

non = *Membranipora dispersa*, Hag.; as stated by Vine, 1893, "Report . . . on Cretaceous Polyzoa," Rep. Brit. Assoc., Edinburgh, 1892, p. 316.

Revised diagnosis. *Rhammatopora* in which the angle of branching is small, 45° or less; the zoœcia taper somewhat distally as well as proximally; the capitulum is bounded proximally by well-curved lines; and the aperture is elliptical.

Distribution. Aptian, Lower Greensand, Shanklin Sand; Maidstone, Kent.

Remarks. Mantell's figures only are available for the interpretation of this species, but the generic and specific characters can easily be seen in them. The branching appears to be somewhat irregular; how far this was so can be settled only if the type is found. Compare the similar case of the figured specimen of *R. gaultina*.

Rhammatopora vinei, n.sp. Pl. XVII, fig. 1.

Synonymy.

Membranipora gaultina, sp. nov.; Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, pp. 484, 461, pl. xix, figs. 13*a–d*; Red Chalk; Hunstanton.

non Membranipora gaultina, sp. nov.; Vine, 1890, *loc. cit.*; Gault; Cambridge. [= *Rhammatopora gaultina* (Vine) q.v.].

non Membranipora gaultina, sp. nov.; Vine, 1890, *op. cit.*, p. 461; Chalk Marl. [Probably = *Rhammatopora pembrokiae*, q.v.].

Membranipora gaultina, Vine; Vine, 1891, Proc. Yorks. Geol. Poly. Soc., new series, vol. xi, part iii, pp. 385, 396; Red Chalk, Hunstanton.

non Membranipora gaultina, Vine; Vine, 1891, *loc. cit.*; Gault; Cambridge. [= *Rhammatopora gaultina* (Vine), q.v.].

Membranipora gaultina, var., Vine: Vine, 1891, Rep. Brit. Assoc., Leeds, 1890, p. 395; Red Chalk; Hunstanton.

Membranipora gaultina, Vine; Vine, 1892, Proc. Yorks. Geol. Poly. Soc., new series, vol. xii, part ii, p. 155; Red Chalk; Hunstanton.

non Membranipora gaultina, Vine; Vine, 1892, *op. cit.*, pp. 154–5, pl. vi, fig. 15; Gault; Barnwell, Cambridge. [= *Rhammatopora gaultina* (Vine), q.v.].

Membranipora gaultina, Vine; Vine, 1893, Rep. Brit. Assoc., Edinburgh, 1892, p. 335; Red Chalk; Hunstanton.

Diagnosis. *Rhammatopora* in which the angle of branching is wide —more than 45°; the zooecia are blunt distally; the capitulum is bounded proximally by nearly straight lines; and the apertures are elliptical.

Type-specimen. British Museum specimen D 2051; Vine's figured specimen of *Membranipora gaultina*, 1890, *op. cit.*, Pl. xix, figs. 13*a–b*; T. Jesson Coll.

Distribution. Albian, Red Chalk; Hunstanton, Norfolk.

Remarks. Although in his first description of *Membranipora gaultina* Vine figured this species, it is clear from this description that he intended the Cambridge Gault specimen for the type and included in the species the Red Chalk and Chalk Marl forms.

RHAMMATOPORA GAULTINA (Vine). Pl. XVII, fig. 2.

Synonymy.

Membranipora gaultina, sp. nov.; Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, pp. 484, 461; Gault; Cambridge.

non Membranipora gaultina, sp. nov.; Vine, 1890, *loc. cit.*, and pl. xix, figs. 13*a–d*; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

non Membranipora gaultina, sp. nov.; Vine, 1890, *op. cit.*, p. 461; Chalk Marl. [Probably = *Rhammatopora pembrokiae*, q.v.].

Membranipora gaultina, Vine; Vine, 1891, Proc. Yorks. Geol. Poly. Soc., new series, vol. xi, part iii, pp. 385, 396; Gault; Cambridge.

non Membranipora gaultina, Vine; Vine, 1891, *loc. cit.*; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

non Membranipora gaultina, var., Vine; Vine, 1891, Rep. Brit. Assoc., Leeds, 1890, p. 395; Red Chalk; Hunstanton. [*Rhammatopora vinei*, q.v.].

Membranipora gaultina, Vine; Vine, 1892, Proc. Yorks. Geol. Poly. Soc., new series, vol. xii, part ii, pp. 154–5, pl. vi, fig. 15; Gault; Barnwell, Cambridge.

non Membranipora gaultina, Vine; Vine, 1892, *op. cit.*, p. 155; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

non Membranipora gaultina, Vine; Vine, 1893, Rep. Brit. Assoc., Edinburgh, 1892, p. 335; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

Revised diagnosis. *Rhammatopora* in which the angle of branching is wide, more than 45°; the zooecia are blunt distally; the capitulum is bounded proximally by well-curved lines; the extra-terminal front wall is small laterally; and the aperture is oval to ovate.

Type-specimen. Vine's type cannot be found; but in his description Vine mentions having by him specimens of this species from the Gault of Cambridge and belonging to Mr. Jesson. British Museum specimen D. 2062 of the Jesson collection and labelled "*Membranipora gaultina*, Cambridge, Gault, in situ" is therefore in all probability a paratype, and in the absence of Vine's examples may be taken as the type specimen.

Distribution. Albian, Gault; Cambridge.

RHAMMATOPORA PEMBROKIAE,[1] n.sp. Pl. XVII, figs. 3 & 4.

Synonymy.

Probably Membranipora gaultina, sp. nov.; Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, p. 461; Chalk Marl.

non Membranipora gaultina, sp. nov.; Vine, 1890, *op. cit.*, pp. 484, 461, pl. xix, figs. 13*a–d*; Gault, Cambridge; Red Chalk, Hunstanton.

[1] In memory of Mary de Valence, Countess of Pembroke, foundress of Pembroke College, Cambridge.

Diagnosis. Rhammatopora in which the angle of branching is more than 45°; the zooecia are blunt distally and taper proximally; the capitulum is bounded proximally by well-curved lines; extra-terminal front wall comparatively wide laterally; rhamma feebly developed, often not visible; aperture ovate to elliptical.

Type-specimen. British Museum specimen D. 22987.

Distribution. Cenomanian, Chalk Marl; N.E. of Cambridge. F. Möckler Coll.

Remarks. The feeble development of the rhamma suggests that this structure disappears during evolution and thus *Rhammatopora* gives rise to *Allantopora.*

II. Charixa,[1] new genus.

In *Rhammatopora* the angle of branching generally is wide, and the caudal portions of the zoœcia, though shorter at the beginnings of each branch (each branch recapitulates a former short-caudal condition), quickly resume their normal length. The resulting zoarium is thus always uniserial both in design and in fact. A form possessing a rhamma and generally resembling *Rhammatopora* has been found in the Albian at Charmouth, Dorset; but the branching is peculiar, and, though strictly bilateral, does not on the whole produce a uniserial zoarium. The caudæ are never very long, and practically absent at branching; moreover the angle of branching is small, as in *Rhammatopora johnstoniana* (Mantell), and the new branches freely branch again on the bilateral method. The zoaria, therefore, though uniserial in principle, often contain patches which are actually multiserial. Two other characters of this genus are the rapid increase in size, so that the daughter zoœcia are often much larger than their parents; and the habit (shared with other uniserial Cretaceous Cheilostomes, but very marked in this form) of eroding the shell it incrusts. In the type-specimen a form of rejuvenescence occurs. In the case of two large zoœcia in a multiserial patch, the terminal buds are small zoœcia with fairly long caudæ and a rather wide angle of branching. The long caudæ are in keeping with a continuation of the branch; but the sudden smallness of size of the zoœcia and widening of the angle of divergence of the branch are a recapitulation of (presumably) earlier conditions in characters in which the lateral branches (which normally recapitulate a short caudal stage) do not recapitulate. The resulting appearance is of new zoaria starting from points on an old zoarium; so it is described here as a rejuvenescence. *Charixa* has been found incrusting *Hoplites splendens* (James Sowerby) in the Albian, zone of *Hoplites interruptus*, and on *Gervillia forbesiana*, d'Orbigny, and *Exogyra conica* (James Sowerby) in the Albian, zone of *Mortoniceras rostratum*, Cowstone horizon, at Black Ven, Charmouth. Also in the Gault of Dunton Green, N. of Sevenoaks, Kent (B.M. specimens D. 23021–4 and a specimen kindly lent me by Mr. A. G. Davis, Hon. Curator of the Croydon Natural History and Scientific Society).

[1] *Carixa*, an old name of Charmouth (the type locality; see Roberts, 1823, "The history of Lyme Regis, Dorset," p. 220), probably = '*Char, isca*' (altered to '*ixa*' as in Exe, Axe, &c.), i.e. "Char river". I have therefore altered the spelling to *Charixa* that this generic name may better recall the locality.

Diagnosis. Incrusting Cheilostome Polyzoa with bilateral branching, and typically uniserial, though actually multiserial patches often occur owing to the smallness of the angle of branching, the frequency of branching and the shortness or absence of caudæ in the first individuals of a branch; zoœcia monomorphic, divided into a distal capitular and a proximal caudal portion which may, however, be very short or even absent; termen beaded; extra-terminal front wall well developed proximally and provided with a rhamma; intra-terminal front wall represented by a narrow bevel tending to become wider proximally.

Genotype. *Charixa vennensis*, n.sp.

Distribution in time. Albian.

Charixa vennensis,[1] n.sp. Pl. XVII, figs. 5 & 6.

Diagnosis. As for the genus *Charixa.*

Type-specimen. British Museum specimen D. 22950; Cowstones; Charmouth; Coll. W. D. Lang.

Distribution. Albian, zone of *Hoplites interruptus*, Bed 3, and zone of *Mortoniceras rostratum*, lower part, Cowstone horizon; Black Ven, Charmouth, Dorset.

III. Pyripora, d'Orbigny.[2]

In 1914[3] in a paper dealing with some uniserial Cretaceous Cheilostomes, I wrongly stated that d'Orbigny founded the genus *Pyripora* on three genosyntypes in his "Prodrome de Paléontologie Stratigraphique", in 1850. As a matter of fact he had already founded this genus in 1849,[2] selecting as his genotype *Criserpia pyriformis* of Michelin,[4] and I take this opportunity of acknowledging my error. *Criserpia* was founded by Edwards[5] for a Cyclostome Polyzoan, and *Pyripora*, therefore, stands as the genus for Michelin's species, which, though not a Cyclostome, is not easily interpreted in detail from Michelin's figure. As far as can be seen from the figure the termen is not beaded and there are no avicularia. It differs from *Herpetopora*, therefore, chiefly in the shortness or absence of the caudæ in the angle of branching and probably in the method of branching. Only a provisional diagnosis, therefore, is given.

Provisional diagnosis. Incrusting uniserial or pauciserial Cheilostome Polyzoa with unilateral[6] (and ? sometimes bilateral) branching; zoœcia monomorphic with very short caudæ or without caudæ; termen plain; extra-terminal front wall well developed proximally, with no rhamma; intra-terminal front wall represented by a narrow bevel, tending to become broader proximally.

Genotype. *Criserpia pyriformis*, Michelin.[4]

Distribution in time. Miocene, Falunian.

[1] From Black Ven, the cliff from which the type-specimen came.

[2] d'Orbigny, 1849, Revue et Magasin de Zoologie, 2nd series, vol. i, p. 499.

[3] Lang, 1914, Geol. Mag., Dec. VI, Vol. I, p. 436.

[4] Michelin, 1848, Iconographie Zoophytologique, p. 332, pl. lxxix, fig. 6.

[5] Edwards, 1838, Annales des Sciences Naturelles, series ii, Zoologie, vol. ix, pp. 208, 238, pl. xvi, fig. 4; *genotype C. Michelinii.*

[6] i.e. with a distal bud and one lateral bud.

IV. Mystriopora,[1] new genus.

In 1846[2] Reuss described two uniserial Cheilostomes from the Cenomanian of Bohemia. One of these, *Escharina dispersa*, Reuss, has been already dealt with and renamed *Dacryopora reussi*.[3] The other, *Escharina perforata*, Reuss, apparently agrees generically with a form washed from the Chalk Marl of Cambridge by the late Mr. F. Möckler. It cannot remain in the genus *Escharina*[4] which was founded by Edwards for twenty-eight recent species differing altogether from the form under consideration. It is therefore here placed provisionally with the Chalk Marl specimen from Cambridge, which is the genotype of a new genus, *Mystriopora*.

Diagnosis. Incrusting, pauciserial Cheilostome Polyzoa with early uniserial stages, and with bilateral to unilateral branching; zoœcia dimorphic; normal zoœcia oval or slightly pyriform with very short caudæ or with no caudæ; termen with spines; extra-terminal front wall well developed proximally; intra-terminal front wall a very small bevel; aperture oval; avicularia small, often a pair placed laterally and distally to each aperture.

Genotype. *Mystriopora möckleri*, n.sp.

Distribution. Cenomanian.

Key to the genus *Mystriopora*.

A. Avicularia rare, without sharp points; zoarium largely uniserial.
1. *M. perforata* (Reuss).

B. Avicularia frequent, sharply pointed; zoarium largely pauciserial.
2. *M. möckleri*, n.sp.

Mystriopora möckleri, n.sp. Pl. XVII, fig. 7.

Diagnosis. *Mystriopora* in which the pauciserial habit is soon attained and the avicularia are numerous and sharply pointed.

Type-specimen. British Museum specimen D. 21670. F. Möckler Coll.

Distribution. Cenomanian, base of Chalk Marl, N.E. of Cambridge.

V. Distelopora,[5] new genus.

Among the material washed by the late Mr. F. Möckler from the Chalk Marl of Cambridge are several specimens of an incrusting Cheilostome, uniserial in its early stages and differing from previously described Cretaceous forms; the following is a diagnosis:

Diagnosis. Incrusting multiserial Cheilostome Polyzoa with unilateral branching, but with early uniserial stages with bilateral branching; zoœcia monomorphic, oval with no caudæ; termen with eight spines of which the proximal pair are widely separate from the distal three pairs and much larger than them; extra-terminal front wall wide laterally and proximally; intra-terminal front wall laterally and proximally is a wide bevel or narrow lamina; aperture ovate to elliptical, somewhat constricted laterally.

[1] *τό μυστρίον*, '*a spoon*'; the normal zoœcia resemble the bowl of a spoon.
[2] Reuss, 1846, Verstein. bohm. kreideform; part 2, pp. 67–8.
[3] Lang, 1914, *op. cit.*, p. 443.
[4] Edwards in Lamarck, 1836, "Hist. Nat. Animaux sans Vertèbres," 2nd edition, vol. ii, p. 230.
[5] *δι-* prefix meaning '*two*' and *ἡ στήλη* '*a post*'.

G. M. Woodward del.

RHAMMATOPORA, CHARIXA, MYSTRIOPORA AND DISTELOPORA.

Genotype. *Distelopora bipilata*, n.sp.
Distribution. Cenomanian.

Distelopora bipilata,[1] n.sp. Pl. XVII, figs. 8 & 9.

Diagnosis. As for the genus.
Type-specimen. British Museum specimen D. 23019. F. Möckler Coll.
Distribution. Cenomanian, Chalk Marl, 10–20 feet from base; N.E. of Cambridge.

VI. A Key to the Cretaceous Uniserial Cheilostome Polyzoa.

In two former papers[2] uniserial Cretaceous Cheilostomes have been dealt with, and for convenience in determination a synopsis of the different genera described is here given.

A. Calcareous portion of intra-terminal front wall confined to a narrow bevel.
- I. No avicularia present.
  - a. Termen plain—no rhamma.
    - 1. Uniserial with bilateral branching with wide angle of divergence . . . . *Herpetopora.* Cenomanian–Danian.
    - 2. Pauciserial or uniserial with unilateral branching with small angle of divergence . . . . *Pyripora.* Miocene.
  - b. Termen with beads or spines.
    - 1. No rhamma . . . . *Allantopora.* Danian.
    - 2. A rhamma present.
      - α. Branching with wide angle of divergence; caudæ long . . . . *Rhammatopora.* Aptian to Cenomanian.
      - β. Branching with small angle of divergence; caudæ short or absent . . . . . *Charixa.* Albian.
- II. With avicularia. Termen with spines or beads.
  - 1. Uniserial with bilateral branching throughout *Marssonopora.* Upper Senonian.
  - 2. Uniserial condition with bilateral branching only in early zoarial stages . . . . . *Mystriopora.* Cenomanian.

B. Calcareous portion of intra-terminal front wall consisting of a very broad bevel or lamina; no avicularia; later zoarial stages multiserial with unilateral branching; proximal terminal spines very large . . . . *Distelopora.* Cenomanian.

C. Intra-terminal front wall entirely calcareous. . . . *Dacryopora.* ? Cenomanian to Senonian.

EXPLANATION OF PLATE XVII.

Fig.
1. *Rhammatopora vinei.* Two zoœcia of the type-specimen (the specimen figured by Vine as *Membranipora gaultina*, Quart. Journ. Geol. Soc., Vol. xlvi, Pl. xix, figs. 13 *a–b*). × about 25 diameters. British Museum specimen No. D. 2051. Albian, Red Chalk. Hunstanton, Norfolk. T. Jesson Collection.
2. *Rhammatopora gaultina* (Vine). Two zoœcia and the cauda of a third which has collapsed along the line of the rhamma. This structure is

[1] bi- prefix meaning '*two*' and pila '*a pillar*'.
[2] Lang, 1914, Geol. Mag., Dec. VI, Vol. I, pp. 5 and 436.

clearly shown in one of the perfect zoœcia but is hardly visible in the other. What may be the remains of a fourth bud occurs on the right-hand side of the zoœcium of the main branch (cf. Vine's figure of his type-specimen, Proc. Yorks. Geol. Poly. Soc., new series, Vol. xii, Pl. vi, fig. 15). × about 27 diameters. British Museum specimen No. D. 2062. Albian, Gault. Cambridge. T. Jesson Collection.

3. *Rhammatopora pembrokiæ.* Three zoœcia of the type-specimen, in one of which the intra-terminal front wall has collapsed along the line of the rhamma. The rhamma is not clearly shown in the other two zoœcia. × about 29 diameters. Part of British Museum specimen No. D. 22987. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
4. *Rhammatopora pembrokiæ.* A single zoœcium of another specimen showing the rhamma. × about 26 diameters. British Museum specimen No. D. 22986. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
5. *Charixa vennensis.* Several zoœcia of the type-specimen showing the method of branching and in one place an example of rejuvenescence. × about 29 diameters. British Museum specimen No. D. 22950. Albian, Upper Gault, Cowstone horizon. Black Ven, Charmouth, Dorset. Collected by W. D. Lang.
6. *Charixa vennensis.* A renewed zoœcium of another specimen, showing the rhamma. × about 35 diameters. British Museum specimen No. D. 22935. Albian, Upper Gault, Cowstone horizon. Black Ven, Charmouth, Dorset. Collected by W. D. Lang.
7. *Mystriopora möckleri.* Several zoœcia of the type-specimen showing the early uniserial stage with bilateral branching passing into a pauciserial stage with unilateral branching. × about 26 diameters. British Museum specimen No. D. 21670. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
8. *Distelopora bipilata.* Several zoœcia of the type-specimen showing the early uniserial stage with bilateral branching passing into a multiserial condition with unilateral branching. × about 28 diameters. British Museum specimen No. D. 23019. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
9. *Distelopora bipilata.* A single zoœcium of another specimen, more adult than those of fig. 8, showing very clearly the number and nature of the spines and the very wide intra-terminal front wall. × about 30 diameters. British Museum specimen No. D. 21883. Cenomanian, Chalk Marl, Cambridge. F. Möckler Collection.

IV.—The Ice Age in England.

By Dr. Nils Olof Holst (late of the Geological Survey of Sweden).

(*Concluded from the October Number, p. 444.*)

IN the preceding paragraphs it has been shown that, after the inland ice had attained its southernmost limit and had spent its force, there commenced in Southern England the last of many stages of land depression. This carried with it a complete reversal: the temperature was raised, the periphery of the inland ice melted, its pressure was lessened, and a rapid rise of the land—the Mousterian elevation—introduced a great rise, to which the origin of the submerged forests bears witness. Nevertheless, the greatest part of the land depression persisted even after Mousterian time, and this explains the continuance of the melting and its increased rapidity, as well as the rapid northward withdrawal of the inland ice, which we shall soon consider.

It is well known to archæologists that after the Mousterian stage, in other words, after the maximum of glaciation, which is usually described as a moist period, that is to say, not too intensely cold, the climate during the Aurignacian and Solutrian stages began to improve. This no doubt led to a rapid and considerable melting of the inland ice, but found no further expression than that it was still possible for the northern animals to remain in Middle Europe. During the Magdalenian period, on the contrary, the winter of the Ice Age returned, now in increased strength, killing off certain pre-glacial animals which had succeeded in living through all the preceding stages of the Ice Age, e.g. the mammoth and the cave bear, and drove others away from Northern Europe, e.g. the lion, the hyæna, and the horse. From this the conclusion may be drawn that during the Magdalenian period the cold was stronger than during the whole of the preceding Ice Age. It was in the Magdalenian that the reindeer first began to thrive in Middle Europe, and indeed became so numerous that the whole of the Magdalenian can with good reason be called 'l'âge du renne'. Another result of the increased cold is the new advance of the inland ice. This resulted in a so-called zone of oscillation.

The milder climate of that part of the Ice Age which is older than the Magdalenian has often evoked the doubt whether the Ice Age really had a cold climate. In 1907 R. F. Scharff [1] reverted to this question, and taking his stand on observations made by himself and others, such as Saporta and Tscherski, expressed the opinion that the climate of the Ice Age was not colder than that at present obtaining. "Saporta," he said, "contended, indeed, from a study of the plants, that the climate of Europe during the glacial period, *at some distance from the glaciers*, was milder, though more humid, than it is now." This is certainly correct if the words here italicized by me be given their due weight, and if the opinion is confined to those warmer phases of the Ice Age to whose rather temperate climate both fauna and flora bear clear witness.

As regards the fauna, it is enough to refer to Déchelette's [2] account of the mammals during the Aurignacian and Solutrian stages. The concordant palæobotanical researches of Carl Weber and N. Hartz have made known the flora in the most southerly districts where the ice first melted in North Germany and Jutland; and this shows, with equal or perhaps even greater clearness than the fauna, that the temperature cannot have been low during this period of melting. But the exhaustive researches of Weber on the peat bogs of Honerdingen near Walsrode, about 50 kilometres north of Hanover,[3] have shown that the peat flora during the warmest time of the formation of the peat indicates a temperature higher than that now obtaining there, "yet not greater than that now obtaining in Thuringia," the middle point of which lies at about two degrees of

[1] R. F. Scharff, 1907. *European Animals*, London, pp. 45–7.

[2] J. Déchelette, 1908. *Manuel d'archéologie*, i, see p. 127 (Aurignacian fauna) and p. 134 (Solutrian fauna). Cf. p. 93 (Mousterian fauna).

[3] C. A. Weber, 1896. "Ueber die fossile Flora von Honerdingen und das nordwest-deutsche Diluvium": Abh. Naturw. Ver. Bremen, Bd. 13, pp. 413–68.

latitude farther south than Honerdingen. From the faunistic and floristic conditions, the conclusion may therefore be drawn that, during this first period of melting, the melting of the inland ice must have proceeded rapidly, and therefore cannot have occupied a long time.

None the less, the Ice Age continuously persisted right from Mousterian times, though not from their first beginning, away to the close of the Magdalenian stage. It is in connexion with that close that *the true late-glacial* stage first appears, and not till after its close does *the true post-glacial* time begin, and with it the second and final melting of the inland ice, which, like the first, was fairly rapid, as is quite clearly proved by the contemporaneous Scandinavian deposits.

It is therefore incorrect and quite misleading to use the terms 'late-glacial' and 'post-glacial' for beds deposited during the first melting stage or between the first and second cold stages of the Ice Age, between the Mousterian and the Magdalenian. Thus the deposits from these intervening stages should be called Intermediate, as they really are.

The danger of this inaccuracy cannot be better emphasized than by reference to the Magdalenian occurrences in the outposts of the Alps (Schweizersbild, Kesslerloch, Schussenried, etc.). These occur in the peripheral moraine district, and have therefore even lately been called by the archæologists 'post-glacial' (as being younger than the moraines), although in reality they are glacial, as belonging to a part of the Ice Age when the cold was as strong as ever.[1]

The same mistake has been perpetrated in the Pyrenees, where the same conditions obtained as in the Alps. There is, however, this difference, that the Pyrenean chain is comparatively small, so that the ice never had so great an extension, and may have been able to melt completely or almost completely during the first melting stage of the Ice Age. This has quite naturally given the Magdalenian occurrences in that region a still greater appearance of being 'post-glacial'.

There has already been occasion to remark (p. 421) that the first melting district of inland ice in North Germany lies between the periphery of the glaciated area and the 'circumbaltic' terminal moraine. In North Germany, then, this constitutes the Intermediate zone. The zone of oscillation here lies near the same moraine.[2]

It is north of this moraine that there first occurs the true post-glacial zone, which thus includes the whole of the Scandinavian

[1] I feel that I cannot be very hard on this mistake, since a little more than ten years ago I fell into a similar error in applying the terms 'late-glacial' and 'post-glacial' to some North German and Danish deposits, although they were so only *locally* and in reality are Intermediate. But that point of view was at that time only subsidiary to the main object, namely, to show that they could not be 'interglacial'. N. O. Holst, 1904. "Kvartärstudier i Danmark och norra Tyskland": Geol. Fören. Stockholm Förh., Bd. 26, pp. 433–52.

[2] This oscillation has long been well known from Kuhgrund, quite close to the town of Lauenburg, and is there fairly clear. It may therefore be appropriately called "the Kuhgrund oscillation".

peninsula. So far as I can see, as I have already emphasized, this is all that remains of the celebrated separate ice ages in North Germany.

The question, then, is this: Are these same three zones also found in Great Britain? I propose to show that such really is the case.

In relation to the intermediate zone of England, the Cresswell Crag caves in the north of Derbyshire are particularly illuminating, since they quite clearly show both when the inland ice came and when it went. They were excavated in 1875–6, as well as in 1878, by J. M. Mello, in part 'assisted' by Th. Heath and W. Boyd Dawkins, and were described in various memoirs,[1] among which the two from 1876 are the more important, in so far as the finds in the different layers were here kept more distinct.

That which lends to these caves their great and unusual interest is the fact that they contain well-characterized deposits of these two ages, namely, the older pre-glacial, deposited before the coming of the inland ice, and the younger intermediate, deposited after its withdrawal, both being characterized by palæolithic implements of older and younger stages and by different faunas, and still further distinguished by an erosion of the uppermost older bed. Naturally there was between the older and the younger deposits a fairly long hiatus, representing the time when the caves were blocked by the inland ice.

A section taken from Robin Hood cave by Mello in 1876 (p. 242) shows the following succession:—

Stalactite uniting breccia with roof.

(*a*) Stalagmitic breccia with bones and implements, 18 inches to 3 feet.

(*b*) Cave earth with bones and implements, of variable thickness.

(*c*) Middle red sand with laminated red clay at base containing bones, 3 feet.

(*d*) Lighter-coloured sand with limestone fragments, 2 feet (?).

Of these beds that lettered (*a*) is Intermediate, and the other layers are pre-glacial. According to Mello's figure 2 of 1876, bed (*a*) lies discordantly upon bed (*b*), and between the two is sometimes found a "bed of waterworn pebbles", which may be cemented into a conglomerate (Mello, 1877, p. 581).

[1] (*a*) J. M. Mello, 1875. "On some Bone-caves in Creswell Crags": Quart. Journ. Geol. Soc., vol. 31, pp. 679–83.

(*b*) J. M. Mello, 1876. "The Bone-caves of Creswell Crags": idem, vol. 32, pp. 240–4.

(*c*) W. Boyd Dawkins, 1876. "On the Mammalia and Traces of Man found in the Robin Hood Cave": tom. cit., pp. 245–58.

(*d*) J. M. Mello, 1877. "The Bone-caves of Creswell Crags": idem, vol. 33, pp. 579–88.

(*e*) W. Boyd Dawkins, 1877. "On the Mammal Fauna of the Caves of Creswell Crags": tom. cit., pp. 589–612.

(*f*) W. Boyd Dawkins & J. M. Mello, 1879. "Further Discoveries in the Cresswell Caves": idem, vol. 35, pp. 724–34.

(*g*) Thos. Heath, 1879. *An Abstract Description and History of the Bone-caves of Creswell Crags*; 8vo, 17 pp., Derby.

(*h*) T. Heath, 1880. *Creswell Caves v. Professor Boyd Dawkins*; 8vo, Derby.

In his "general conclusions" Boyd Dawkins (1879, p. 733) divides the mammalian fauna into three divisions: (1) the lowest, known from Mother Grundy's Parlour, with *Hippopotamus*, *Rhinoceros leptorhinus*, and *Hyæna* (abundant), therefore an older, clearly pre-glacial fauna, comparable with that from the older pre-glacial beds of Kirkdale, Victoria Cave, and Cefn Cave; (2) a later pre-glacial fauna with the forerunners of the Ice Age, mammoth and woolly rhinoceros, and in addition the reindeer, glutton, and polar-fox (the two last come from Pin Hole), which are all absent from the preceding division, but without the *Hippopotamus* and *Rhinoceros leptorhinus*; and finally (3) the Intermediate fauna, which occurs in the breccia and "differs considerably from those of the underlying strata" (Dawkins, 1876, p. 246).

The most weighty evidence, however, is furnished by the implements, and is absolutely conclusive. Boyd Dawkins and John Evans were agreed that the older implements, which as a rule are made of quartzite or ironstone, are to be referred to the older palæolithic stages; Acheulean and Mousterian were mentioned. The younger implements, on the other hand, as a rule made of flint, agree according to Evans with the Aurignacian, Solutrian, and Magdalenian, and thus belong to younger palæolithic stages. Prestwich (in the Discussion on Dawkins, 1876) remarked that the superposition of the better younger implements over the worse older ones "was better marked in this cave [Robin-Hood cave] than in any other in this country". So far as may be judged from the figures, there are found among the older implements partly Chellean (e.g. the ironstone implement, fig. 2 of 1877, p. 593), partly Acheulean (e.g. two oval implements, one of quartzite, the other of ironstone, figs. 4 and 5 of 1876, p. 251),[1] but, to whatever stage they may be assigned, all of them remain pre-glacial. Aurignacian, Solutrian, and Magdalenian, on the other hand, cannot possibly be pre-glacial. They must have come into the caves after the melting of the inland ice. From this may be drawn the important conclusion that *the inland ice melted away from the Thames Valley right up to the northern point of Derbyshire*, or perhaps still further north, *before the close of Aurignacian time.*

An equivalent of the succession in the Cresswell caves is found in North Wales in the caves near St. Asaph. In the Pont Newydd cave, together with a distinctly pre-glacial fauna (*Hippopotamus*, *Rhinoceros leptorhinus*, *Elephas antiquus*, etc.) there have been found both a human molar tooth and "quartzite implements, which may be classified with those of the lower strata in Mother Grundy's Parlour",[2] one of the previously mentioned caves at Cresswell Crags. What is still more important here, however, is the fact that in the Ffynnon

[1] Dawkins (*Early Man in Britain*, 1880, p. 180) states that the caves at Cresswell Crags yielded "implements of flint and quartzite amounting to not less than 1100". These are said to be preserved in the Manchester Museum. Of these barely a score have as yet been figured. The finds of the Cresswell caves are, however, of such great scientific importance that they deserve from archæologists a renewed and more detailed investigation than was possible in the seventies.

[2] W. Boyd Dawkins, 1880. *Early Man in Britain*, p. 192.

Beuno cave there has been found a Solutrian implement, and in Cae Gwyn cave a beautiful Aurignacian end scraper,[1] finds which clearly show that in this part of North Wales the inland ice had melted away at about the same time as in the northern district of Derbyshire.

In common with other finds, those just quoted from Derbyshire and North Wales show that it is far from correct to draw the limit for the appearance of palæolithic man "between the Wash and the Bristol Channel", as is so often done. The numerous finds of Chellean age show that during this stage man was far from rare in England. For him to have stayed to the south of such a limit would therefore have been inexplicable. It is true that the northern finds are less frequent, but this may be explained by the absence of Chalk flints from the district in question, but certainly also by the thicker moraine covering, which there conceals to a greater degree everything that is pre-glacial, to which may be added that implements of quartzite and such rocks are less easily detected than flint implements.

With regard to post-Chellean time, the possibility is not excluded that the Ice Age may have driven some part of England's palæolithic population back to the Continent, while the land bridge still existed. One is inclined to this supposition by the comparative paucity of noteworthy Mousterian localities. As such are mentioned only: Stoke Newington, Crayford, Northfleet, Dovercourt near Harwich, High Lodge near Mildenhall, and Peterborough. The more scattered Mousterian finds in the South of England, on the other hand, are less rare.

After this little archæological digression we return to one of the St. Asaph caves. H. Hicks has published a section of the Cae Gwyn cave, which shows that two inconsiderable moraine beds, separated by a layer of sand and lying on another layer of sand, overlie the intermediate cave-earth, in which has been found a flint flake and in which the previously mentioned end scraper was found.[2] He showed his section to various experienced geologists, who accepted it, and in the discussion after Hicks' paper Strahan said that he "believed that the drifts at the mouth of the cave were part of the northern drift, which he had mapped over a large part of Denbighshire, Flintshire, and Cheshire, and that the bone-earth lay beneath them". If, then, the section is quite correct, we must here at St. Asaph have a new extension of the inland ice, that is to say, we are here already within the zone of oscillation between the two melting districts of the inland ice. The correctness of such a conclusion is confirmed by the correspondence between this section with "little moraine and most sand", and sections from the North German zone of oscillation. It is also noteworthy that, while the locality Kuhgrund in the last-mentioned zone lies about on the latitude of 53° 20′–25′, St. Asaph lies in latitude about 53° 15′.

[1] H. Hicks, 1886. "Results of Recent Researches in some Bone-caves in North Wales (Ffynnon Beuno and Cae Gwyn)": Quart. Journ. Geol. Soc., vol. 42, pp. 3–17, see pp. 9, 11, figs. 5, 9.

[2] H. Hicks, 1888. "On the Cae Gwyn Cave, etc.": Quart. Journ. Geol. Soc., vol. 44, pp. 561–77, see p. 563, fig. 1.

The oscillation in question appears still more clear in the East of England at Kirmington, in the northern part of Lincolnshire, and at Flamborough in Yorkshire. Here are found beds with marine molluscs between an older and a younger moraine, affording sufficient proof of the existence of the oscillation; and it is not too bold a prophecy to assert that the future will yield many further proofs, even though they be not so clear as the sections at Kirmington and Flamborough. It is convenient to give this oscillation a special name in England also, and since it is so well known from Kirmington, the name "Kirmington oscillation" seems not inappropriate.

There now remains the question: Where does the third zone, the post-glacial zone begin? On the Continent the circumbaltic terminal moraine affords an approximately southern limit for it. This terminal moraine may be, and has been, traced from Russia, through the whole of Northern Germany and Jutland, down to the east coast of the North Sea. Can it be supposed that it is not to be found again on the west side of the North Sea? I have long had the suspicion, not to say firm belief, that the two fine terminal moraines which pass from the city of York in a north-easterly direction to the east coast of England, and are after the usual fashion of these large terminal moraines in connexion with large sandy plains, constitute this very continuation on the English side. The mapping by the Geological Survey ends, however, just by the city of York, and the westerly continuation of the terminal moraines is therefore not known, but certainly it will be possible to find it. Probably it will be traceable, not only through England, but also across the whole of Ireland. The phenomenon is far too vast a one to come to a capricious and sudden end. The task of tracing these important terminal moraines down to the Atlantic seaboard would be no unprofitable one, but I must leave it in the hands of my English and Irish colleagues.

This section on the great and geologically important distinction between the Intermediate and post-glacial zones cannot be brought to a more appropriate conclusion than by reprinting the following utterance by Boyd Dawkins:[1] " . . . Cumberland, Westmoreland, Lancashire, and the greater portion of Yorkshire are represented as being one of these barren areas, in which no pleistocene mammalia have been observed. It is obvious that the hyænas, bears, mammoths, and other creatures found in the pleistocene stratum could not have occupied the district when it was covered by ice; and had they lived soon after the retreat of the ice-sheet, their remains would occur in the river-gravels, from which *they are absent throughout a large area to the north of a line drawn between Chester and York*, whilst they *occur abundantly* in the glacial river deposits *south of that line*."

This was printed in 1874. It could not then be known, as we now know, that this so-called 'line' is really the great Magdalenian zone of demarcation between the Intermediate stage, with the hyæna and mammoth still existing,[2] and the post-glacial period when these creatures were extinct.

[1] W. Boyd Dawkins, 1874. *Cave Hunting*, pp. 123–4. The italics are mine.

[2] The mammoth skeleton which was found a few years ago at Borna, near Leipzig, together with Arctic plant-remains, belongs to the older part of the Intermediate zone.

Some important questions in this connexion are those relating to contemporary conditions in the North Sea. When did the Scandinavian inland ice disappear from England? Or, in other words, when did the ice cease to block the North Sea? How rapid was the elevation that began in Mousterian time, and when did there succeed the last change of level, the depression of "the submerged forests"?

During the maximum of glaciation the Scandinavian inland ice came to England in great force, and has left its traces right down the Thames Valley in the south and up to Hartlepool and Durham in the north. The inland ice, however, took a curve to the north in the neighbourhood of the North Sea, and probably also in the Sea itself. Both on the English and Dutch sides proofs of this may be seen. While in the neighbourhood of London the ice comes quite close to the Thames Valley; on the coast of the North Sea it does not come further than to the district between Suffolk and Essex; and while in Holland it comes near the Rhine, where this river runs into the Dutch district, on the coast it reaches only down to the southern end of the Zuyder Zee. The same conditions obtained at the beginning of the post-glacial time, when the southern limit of the inland ice is precisely indicated by the large terminal moraine. From York, in latitude 52° 52′–53′, the terminal moraine passes to the north-east, and on the continental side the greater melting in the neighbourhood of the North Sea is still more clearly accentuated. The circum-baltic terminal moraine, coming from the east, has a direction east and west, but takes a sharp turn northward as it passes from Mecklenburg into Holstein, and here, as well as in Schleswig, comes much closer to the east than to the west coast, after which, in Jutland, it takes a new western curve down to the coast of the North Sea, which it first meets in latitude 56° 30′.

Here the important fact must be recalled that on the continental side within the Intermediate zone there have been found marine deposits, "Arctic clay covered by boreal sand," along the east coast of the North Sea, from Lamstedt and Basbeck south of the Elbe in the south up to the Jutland locality, Hostrup, in the north. Intermediate localities are Burg and Esbjerg. The most southerly occurrences lie at a height of 5 to 7 metres above sea-level, the most northerly at a height of 27 metres,[1] from which follows the conclusion that at the time of their deposition the land was more depressed in the north than in the south. Further, since these beds, deposited in an open North Sea, show by their Arctic character and in other ways that they belong to the earliest portion of the Intermediate stage, the conclusion follows that the blocking of the North Sea by the Scandinavian inland ice ceased quite early, probably shortly after the disappearance of the Hesbayan lake, or, in other words, just at the beginning of the Intermediate time.

The elevation of the land at that time is, naturally, not easy to prove, since that part of the sea-floor which then lay above the surface of the water now lies sunk beneath it. The post-glacial changes of level on the other hand appear simpler, and if, as is

[1] Holst, 1904. *Kvartärstudier*, etc., pp. 433–9.

probable, they proceeded in analogous fashion to the last Scandinavian movements, they may be supposed to have taken place somewhat in the following way.

After the inland ice during post-glacial times had melted so much that its pressure was notably diminished, the whole of Scotland, and perhaps also the most northern part of England, began to rise, but at the same time the remaining part of England sank. In a word the land behaved something like a see-saw; when the one (northern) end went up, the other (southern) end went down. Probably both the up and the down movement increased with distance from the fulcrum of the see-saw, that is, from the line of equilibrium, which in this particular case seems to have been the border between England and Scotland. At any rate, something similar was the case in Scandinavia, where the line of equilibrium is held to proceed in Denmark from Nissum Fiord west of Holstebro, lat. 56° 20′ N., on the west coast of Jutland in the north, down to the northern part of Falster in the south.[1]

In Southern Scandinavia this change of level carried with it the evident and very interesting result that the well-known kitchen-middens, which originally lay on the shore very little above sea-level, have come to lie higher and higher *above* sea-level the further they are north of the Nissum–Falster line, but lower and lower *under* sea-level the further they are south of that line. Thus the kitchen-middens at Kolding now lie 3 to 4 metres below sea-level, but the kitchen-middens in Kiel Harbour, 140 kilometres further south, are not less than 9 metres below sea-level.

If this result is applicable to England, it is clear that the English kitchen-middens, as well as all coast deposits approximately contemporaneous with the Danish ones, must now lie below sea-level, and be therefore inaccessible. The so-called Hastings kitchen-midden is merely a fisherman's dwelling-place of far later neolithic date.

The circumstances just mentioned can therefore in no way be adduced as evidence against the idea that the kitchen-midden civilization and its bearers came to the north by the so-called 'western way' or the Atlantic coast road. I am the more convinced of this since I consider that it can be shown, and in part indeed already has been shown, that Egypt, which, during the pluvial epoch was a 'promised land', was also a centre of civilization for the whole of Europe right from the earliest palæolithic time down almost to the close of the Stone Age, and in general sent its civilization into Europe by the roads along the south and west of the Mediterranean. Clearly this was still so after the kitchen-midden time, as shown by the distribution of the megalithic monuments — the dolmens and the long barrows or chambered barrows (in Swedish: *gång-grifter*). For these monuments follow without exception the Atlantic coast lands—France, England, and Holland, to continue subsequently over North Germany to Scandinavia, but are not found in the interior of Europe. Therefore it cannot be correct to consider the main neolithic immigration to Scandinavia

[1] N. V. Ussing, 1913. *Danmarks Geologi*, København, see pp. 327–8.

as having been Indo-European and coming by the 'eastern way', a view which none the less is still generally held in Scandinavia. But it is plain that, if the western way of migration to the north was still used as late as the time of the long barrows, so much the more probably was it that road which was used during the preceding stage of the kitchen-middens.

The end of my task is now reached. Within the limits of Great Britain the Ice Age can be followed from its beginning to its end. England has the further advantage of having already possessed quite a numerous population before the Ice Age, and has been inhabited ever since. Archæology can therefore lend a strong support to glacial geology. It was these fortunate English conditions which originally gave me the idea of attempting this brief general synopsis of the course of the Ice Age in this country. I cannot, however, lay down my pen without expressing my hearty thanks, in the first place to England, which, in the midst of this world-war and general disturbance, has given me a calm and peaceful lodging from the very beginning of the war, when I came here headlong, down to the present when I return to my Fatherland; and also to my English friends, new and old, unnamed but unforgotten, who have lent me a hand and facilitated my geological studies in England.

V.—The Crawfordjohn Essexite and Associated Rocks.

By Alexander Scott, M.A., B.Sc.

(*Concluded from the October Number, p. 461.*)

ANOTHER type, which is found in both quarries and which under the microscope has the aspect of a monchiquite or limburgite, probably represents the actual marginal rock of the intrusion.[1] It consists of small microphenocrysts of augite and olivine in a dark matrix, which can be resolved into granular augite and magnetite in a nearly isotropic base. The latter, which sometimes contains felspar microlites, seems to be mainly analcite with some nephelite, as it can be readily gelatinized and stained, while the refractive index is very low. The felspar microlites are small and sometimes have a rough trachytic structure resembling that of the mugearites. Following Harker's suggestion that augite-olivine rocks with an isotropic base should be classed as limburgites when the base is glass and as monchiquites when it is analcite,[2] this rock can be included in the latter group. The parts which are richer in felspar may be termed analcite-basalts.

A sample of monchiquite from the large quarry has been analysed, and the results are given in column 1, table iii. The rock does not differ much in chemical composition from the essexite. The silica content, however, is noticeably lower, while the amounts of iron oxides and alumina are slightly higher. While the amounts of augite in the two rocks are probably very similar, the increase in magnesia and ferrous oxide in the monchiquite, coupled with the lower silica-content, indicates a greater proportion of olivine.

[1] This rock was first brought to my notice by Mr. W. R. Smellie.

[2] *Petrology for Students*, 4th ed., 1908, p. 158.

Analyses 2 and 3 represent two basic monchiquites, and the fact that the Craighead rock is intermediate in composition between these two, shows a close relationship to this group. A recalculation of analysis 2, after deduction of the amount of CO_2, would bring it fairly close to analysis 1. A comparison of columns 1 and 4 indicates a high degree of affinity with the nephelite basalts. Several occurrences of the latter have been noted among the Carboniferous lavas and intrusives of the Midland Valley,[1] where they exhibit some

TABLE III.

	1.	2.	3.	4.	5.	6.
SiO_2 .	40·79	37·34	42·03	40·01	40·60	40·10
TiO_2 .	1·79	3·93	3·70	1·45	4·20	2·98
Al_2O_3 .	15·54	11·84	13·60	13·44	12·55	15·50
Fe_2O_3 .	3·90	5·37	7·55	5·32	5·47	6·35
FeO .	9·48	6·40	6·65	7·22	9·52	7·29
MnO .	·20	·18	tr.	·30	—	—
MgO .	8·61	9·66	6·41	9·46	8·96	8·41
CaO .	12·71	11·92	14·15	14·06	10·80	12·40
Na_2O .	3·44	2·91	1·83	3·38	2·54	3·37
K_2O . .	2·05	2·05	·97	1·90	1·19	1·67
H_2O + .	·60	2·56	1·08	1·94	2·28	·87
H_2O − .	·58	·24				
P_2O_5 .	·47	·04	·57	1·36	2·68	1·28
CO_2 . .	not found	5·08	—	—	—	—
(Ba . Sr.) O.	tr.	·04	—	—	—	—
	100·16	100·09	99·23	99·84	100·79	100·22

1. Monchiquite, Craighead, analyst A. Scott.
2. Monchiquite, Mile End, Montreal (includes ·47 Fe S_2), analyst M. F. Connor.[2]
3. Monchiquite, Pulaski Co., Arkansas, analysts Noyes & Bracket.[3]
4. Average of ten analyses of nephelite-basalt.[4]
5. Camptonite, Maena, Norway, analyst L. Schmelk.[5]
6. Ijolite, Ambaliha, Madagascar, analyst Pisani.[6]

similarity with the Hillhouse type,[7] merely differing from it in the presence of nephelite and the smaller amount of olivine. Since the Hillhouse basalts may be regarded as the microporphyritic equivalents of the Craiglockhart type, it is significant that, while the Craighead aphanites are related to the former, the essexites are not far removed from the latter.[8] Analyses 1 and 6 resemble each other so closely that the Madagascar ijolite may be regarded as a plutonic equivalent of the rock under consideration.

The microscopical and chemical examinations of the Craighead rocks give some clue as to the nature of the differentiation. The augite of the marginal rocks is zoned to a much greater extent than

[1] E. B. Bailey in *Geology of East Lothian* (Mem. Geol. Surv.), 1910, p. 99, pp. 105–13.

[2] Geological Congress, Canada, 1913, Guide-book No. 3, p. 46.

[3] Quoted in Iddings, *Igneous Rocks*, vol. ii, p. 413, 1913.

[4] Compiled from H. Rosenbusch, *Elemente der Gesteinslehre*, 3rd ed., 1908, and J. P. Iddings, *Igneous Rocks*, vol. ii, 1913.

[5] W. C. Brögger, loc. cit., p. 26.

[6] A. Lacroix, loc. cit., p. 138.

[7] Cf. J. S. Flett, loc. cit., p. 316; E. B. Bailey in *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, p. 138.

[8] Cf. E. B. Bailey, loc. cit.

the mineral of the essexites, and shows a greater difference between the extinction angles of the inner and outer zones. This points to the former mineral crystallizing during a rapid fall of temperature, since the tendency of mix-crystals to show zonal structure increases with the rate of cooling during crystallization, owing to the shorter time available for readjustment of equilibrium. Hence it is feasible to assume that the 'chilling' set in before the pyroxene began to crystallize. There is, however, very little difference between the olivine of the two rocks, which suggests that this mineral commenced to crystallize before the inception of rapid cooling. While the relatively greater amount of olivine in the chilled rock is doubtless partly due to the rapid cooling ensuing before the olivine had finished crystallizing, and hence preventing, to some extent, resorption and subsequent reprecipitation as pyroxene,[1] the main factor seems to be the difference in chemical composition, i.e. the greater amounts of magnesia and ferrous oxide and the smaller silica content.

This difference in composition may be explained in two ways. Firstly, it may be due to the migration of orthosilicate molecules to the cooling margin during the crystallization of the olivine. This migration may have taken place by diffusion, as suggested by Harker,[2] or by means of convection-currents, as advocated by Becker[3] and Pirsson.[4] Washington's view[5] that it is to be attributed to "the force of crystallization", which is supposed to be capable of acting at an appreciable distance, can be explained in terms of the diffusion hypothesis in the following way. The concentration of a solution in the immediate neighbourhood of a growing crystal will be lowered by the tendency of the molecules of the solute to attach themselves to the crystal. Hence an osmotic-pressure gradient will be set up, and in order to restore equilibrium there will be a transference of molecules by diffusion from the remainder of the solvent. The second explanation of differentiation of this type is due to Bowen,[6] and is based on the gravity-separation of the crystals. While the minerals of early formation (in this case olivine) are crystallizing, the action of gravity tends to make them sink. In the chilled margin, however, the rate of cooling is sufficiently rapid to prevent this sinking taking place to the same extent, as it is hindered not only by increasing viscosity but also by the crystallization of the remaining minerals. The second explanation has the advantage over the first in being based on experimental work and being less dependent on hypothesis. In the present case, however, the depth of exposure is too small for the detection of any gravity sinking in the essexite, though it is possible that a more basic layer may exist at a greater depth. It is noteworthy that while the essexite has nearly the same chemical composition as the Brandberget rock, the monchiquite

[1] N. L. Bowen, Amer. Journ. Sci. [4], xxxviii, pp. 256–8, 1914.
[2] A. Harker, *Natural History of Igneous Rocks*, 1908, pp. 317–20.
[3] G. F. Becker, Amer. Journ. Sci. [4], iii, pp. 21–8, 1897.
[4] L. V. Pirsson, Bull. U.S. Geol. Surv., No. 237, pp. 187–90, 1905.
[5] H. S. Washington, Bull. Geol. Soc. Amer., xi, pp. 409–10, 1900.
[6] N. L. Bowen, Amer. Journ. Sci. [4], xxxix, pp. 175–90, 1915.

closely resembles the camptonite (column 5, table iii), which Brögger regards as a complementary differentiate of the essexitic magma of the Gran district.[1]

The Contact Metamorphosed Rocks.—In both quarries an interesting set of altered rocks is found in contact with the margin of the intrusion. The sediments range from greywackes and grits, of varying degree of coarseness, to fine-grained mudstones and shales. The grits and greywackes, which consist of rounded grains of quartz and felspar, together with rock-fragments, are not much altered, the alteration being more or less confined to the matrix, and being therefore more noticeable in those rocks with a comparatively small proportion of granular material. In the more altered rocks the grains seem to have undergone some corrosion, while the matrix has been completely recrystallized. The chief 'new-formed' minerals comprise ilmenite, in small eumorphic crystals, which are often brown in colour and translucent, and small greenish prisms with a good cleavage, which seem to be muscovite altering to chlorite. The remainder of the matrix, which is stained by iron oxide, is felsitic in structure and appears to be an aggregate of felspar. Some of the rocks contain microlites of felspar, while others have bunches of hair-like crystals, which are probably rutile, and sporadic flakes of strongly pleochroic biotite.

The shales, however, have undergone a much greater amount of metamorphism. In one rock which occurs in the large quarry numerous lath-shaped crystals can be seen in the hand-specimen, while within the space of 3 inches there is a passage to a thoroughly aphanitic, compact rock with no recognizable minerals. Under the microscope the former rock shows rather a remarkable structure, as it consists entirely of interlocking, irregularly shaped crystals of colourless cordierite, which enclose all the other constituents. The outlines of the cordierite grains are not usually visible in ordinary light, but between crossed nicols the crystals appear as irregular prisms. Simple twinning is very common, but multiple and complex twins are rare. Of the enclosed minerals, muscovite, often altered to chlorite, is the most abundant. Biotite and ilmenite are also present and occasionally predominate in certain bands, the determining factor being the composition of the particular band. This cordierite-hornfels has a close resemblance to the cordierite schist described by Harker from the Skiddaw district.[2] Not only is the cordierite quite fresh and unaltered in both instances, but it also constitutes a coarse-grained groundmass in which the remaining, much smaller, crystals are set. As the compact rock is approached the grain-size of the cordierite diminishes and the crystal boundaries become indistinct, so that finally the rock consists of small crystals of muscovite with subordinate biotite and rutile in a fine-grained matrix of cordierite.

Another type of altered argillaceous rock occurs in the small quarry and also further up on the hillside. Under the microscope, the rock is seen to consist of a great abundance of minute crystals of muscovite with subsidiary ilmenite in a groundmass, which is partly composed

[1] W. C. Brögger, loc. cit.
[2] A. Harker, *The Naturalist*, pp. 121–3, 1906.

of dusty cryptocrystalline material and partly of clear grains of felspar. Under a low-power objective the latter appear as small rhomb-shaped crystals, but a high power shows that they are irregular in shape and have no definite crystal boundaries, merging gradually into the dusty material. The felspar seems to be an acid oligoclase as the refractive index is sometimes below that of Canada balsam and sometimes above. This rock has some resemblance to a fine-grained adinole, and only differs from the latter in the presence of some anorthite in the felspar.[1] A portion of the soda in the mineral has probably been introduced from the intrusive rocks and the fact that oligoclase is present, instead of albite as in the typical adinoles, may possibly be ascribed to the presence of calcium oxide in the original sediments. One fact in favour of the idea that the intrusive rock is the origin of the soda is the existence of numerous veins of adinole much coarser in grain than the rest of the rock. These veins consist of a core of muscovite, sometimes replaced by decomposition products and flanked by bands of clear felspar. In other cases, the relative disposition of the mica and felspar is quite irregular. The veins often cut across the bedding planes in an irregular fashion, but occasionally they lie along the latter. This is particularly the case along the junction of two different types of sediment, which are usually found separated by a band of fairly coarse adinole.

In the disused quarry, several types of rock, whose original nature is doubtful, are found. One type, which in the hand-specimen shows faint spherulites, is seen under the microscope to consist of numerous microcrystalline patches set in a cryptocrystalline matrix. The former consist of groups of clear felspar, permeated with dark material, which under a high-power objective can be resolved into aggregates of greenish microlites apparently of a pyroxenic nature. Dark elongated masses of similar material are scattered throughout the groundmass and appear to represent former crystals of mica or hornblende. Occasionally new-formed ilmenite is found. Sometimes clots and bands of a rather different nature are found enclosed in this rock. The ferromagnesian areas are more rounded, while the felspar, which occurs as small laths, is uniformly distributed throughout a cryptocrystalline groundmass. The felspars appear to be oligoclase, as they have a low extinction angle and a refractive index above that of Canada balsam. Parts of the groundmass have a lower refractive index, and may be orthoclase.

As the intrusion is approached the felspathic rock assumes a more decidedly porphyritic aspect. The felspars, which show broad rectangular sections, are sometimes arranged in groups and sometimes found as single crystals. The mineral is perfectly colourless and fresh and sharply delineated from the groundmass. Carlsbad twinning is universal and albite twinning fairly common, while occasional striations following the pericline law can be observed. The refractive index and extinction angles indicate a composition approaching andesine. Occasionally phenocrysts of orthoclase are also found.

[1] Cf. J. Roth, *Chemische Geologie*, vol. iii, 1893, pp. 141–4; H. Dewey & J. S. Flett, Geol. Mag. [5], vol. viii, pp. 243–4, 1911.

Dark aggregates of ferromagnesian microlites suggest the original presence of porphyritic mica or hornblende. The groundmass is generally felsitic and, from the refractive index, seems to contain a fair amount of orthoclase, a fact borne out by the quantity of potash in the analysis. This rock has been analysed, the results being given in column 1, table iv. In chemical composition it closely resembles the albite-diabase of Trusham, Devon (column 2), while it also shows some similarity with the keratophyres. The former rock consists mainly of broad rectangular crystals of alkali-felspar with interstitial chloritic material, and is therefore very like the crystalline aggregates in the Craighead rock. In the neighbourhood of Abington there are several outcrops of lavas and intrusive rocks of Ordovician age, and it seems probable that the rock in question is related to these. The felspars are so fresh that they must

TABLE IV.

	1.	2.	3.	4.
SiO_2 . .	58·25	58·47	64·38	58·80
TiO_2 . .	1·08	1·18	—	·40
Al_2O_3 . .	15·52	16·11	16·98	17·03
Fe_2O_3 . .	2·26	·85	4·04	2·44
FeO . .	6·00	6·90	—	5·81
MnO . .	·12	·46	—	—
MgO . .	2·20	1·58	·28	1·83
CaO . .	2·14	·94	1·08	1·16
Na_2O . .	4·81	4·34	7·57	5·22
K_2O . .	4·26	5·18	4·30	4·27
H_2O+ . .	3·03	2·08	1·64	2·68
H_2O- . .	·67	.48		
P_2O_5 . .	·08	·27	—	·11
CO_2 . .	not found	1·34	—	·75
	100·42	100·31	100·27	100·61

1. Altered lava (?), Craighead, analyst A. Scott.
2. Albite-diabase (felspathic type), Trusham, Devon, analyst E. G. Radley (includes ·07 Cl., ·08 BaO, ·03 FeS_2).[1]
3. Keratophyre, Hamilton Hill, Peebles, analyst J. J. H. Teall.[2]
4. Keratophyre, Blankenburg, Harz (includes ·11 SO_3).[3]

have been completely recrystallized and their composition and form suggest some infiltration of material from the essexites. The felspars of the diabases of Devon and Cornwall are usually albitized, a phenomenon which also occurs in the Southern Uplands. The relatively basic nature of this mineral in the Craighead rock may be due, as suggested above, to the introduction of material during the metamorphism. This renders the determination of the original nature of the rock difficult, but it seems probable, from a consideration of the chemical analyses, that it was originally a felspathic diabase or proterabase, resembling a trachyte in composition and having porphyritic crystals of felspar and either mica or hornblende in a fine-grained or glassy matrix.

A thin band in the greywacke above the quarry appears to have

[1] J. S. Flett in *Geology of Newton Abbot* (Mem. Geol. Surv.), 1913, p. 62.

[2] J. J. H. Teall in *The Silurian Rocks of Scotland* (Mem. Geol. Surv.), 1899, pp. 88–9.

[3] Quoted in Rosenbusch, *Elemente der Gesteinslehre*, 3rd ed., 1910, p. 343.

been a tuff, as it contains rounded but clear crystals of felspar, abundant dark aggregates of ferromagnesian crystallites and fragments of a rock which was probably an andesite. The felspar has again been recrystallized, and the shape of the microlitic patches indicates former phenocrysts of hornblende. In the andesite fragments small clear felspar laths are found, as well as an altered bisilicate mineral in which occasionally unaltered traces of augite appear.

As a whole, the metamorphism differs from that developed round the granites of the Southern Uplands, in the absence of such characteristic minerals as andalusite and garnet.[1] Although the sediments are so much obscured as to preclude any possibility of examining their progressive metamorphism, it is very probable that the altered aureole is narrow, extending to not more than a few feet.

Nature and Age of the Intrusion.—Judging from the extent of the exposures, the intrusion is not less than 250 yards long and 25 yards broad. Indeed, the breadth is probably much greater as the most southerly exposure is a very coarse-grained rock. If it were a dyke, it might be expected that it would be seen in the Duneaton water, 400 yards to the north-west and 200 feet lower than the large quarry. Although the grits and greywackes are exposed along the bed of the stream, no trace of igneous rock could be found, either in the stream or on the opposite hillside. Further, there is no evidence of any continuation to the south-west, on Craighead hill or in the Clyde Valley. The nature of the igneous rocks, as well as the field relations, indicates that the intrusion is probably a small elongated boss. Its form is rather like that of the Lennoxtown essexite which, although originally described by the Geological Survey as "an irregular dyke of great thickness",[2] is classed in the Glasgow memoir as "an elongated plug or small boss".[3] The Craighead intrusion may be regarded as very similar, not only morphologically but also lithologically, the only difference being the absence, so far as is known, of any chilled margin in the Lennoxtown occurrence. Although the Geological Survey express no definite opinion regarding the age of the latter, they indicate that it is probably Carboniferous or Permo-Carboniferous. There does not seem to be any doubt that the Craighead intrusion has no connexion with the Kainozoic dykes, and that it must be referred to the late Palæozoic alkalic suite. Its great petrographical resemblance to the Ayrshire representatives of the latter group is strongly in favour of this, and, although the field evidence only indicates a post-Llandeilo age, the lithological evidence seems to preclude any connexion with either the Old Red Sandstone or Kainozoic rocks. Adopting Tyrrell's suggestion that the dominantly alkali rocks of late Palæozoic age are Permo-Carboniferous,[4] the Craighead intrusion may be referred to this epoch.

[1] Cf. M. I. Gardiner, Quart. Journ. Geol. Soc., xlvi, pp. 569–81, 1890; J. J. H. Teall, loc. cit., pp. 632–49.

[2] Summary of Progress of Geological Survey for 1907–8, p. 55; ibid. for 1908–9, p. 45.

[3] E. B. Bailey, *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, p. 113.

[4] G. W. Tyrrell, Trans. Glasgow Geol. Soc., xiii, p. 311, 1909; Geol. Mag. [5], ix, pp. 129–31.

NOTICES OF MEMOIRS.

Papers read before Section C (Geology), British Association, Manchester, September, 1915.

I. The Classification of the Tertiary Strata by means of the Eutherian Mammals. By Hon. Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S.

THE classification of the Tertiary strata by means of the higher mammalia outlined in my paper before the Geological Society in 1880[1] has been tested by the many discoveries all over the world since that time, and not found wanting. The details have been filled in, and the principle adopted has been proved to be of worldwide application to North and South America and to Southern Asia and Africa as well as Europe, the living mammalian species in each geographical province being taken as the standard. It has been accepted by Osborne and others, and is now being used for the grouping of the Tertiary strata of America. It has been used in the organization of the Manchester Museum. It is therefore fitting that it should be brought up to the knowledge of to-day.

The classification is based on the evolution of the mammalia, the only group in the animal kingdom that was, as Gaudry writes, "en pleine évolution" in the Tertiary Period, all the lower forms having already undergone their principal changes and none changing fast enough to be of service in defining the stages. The scheme is as follows:—

Table of the Divisions of the Tertiary Period.

Descriptions.	*Characteristics.*
Historic, in which the events are recorded in history.	Modern types of man. Man the master of nature.
Prehistoric, in which man has multiplied exceedingly and domesticated both animals and plants. Wild Eutheria on the land of existing species, with the exception of the Irish elk.	Modern types of man. Cultivated plants. Domestic animals—dog, sheep, goat, ox, horse, pig, etc. Wild Eutheria of living species.
Pleistocene, in which living species of Eutheria are more abundant than the extinct species. Man appears.	Extinct types of mankind. (Modern types ?) Living Eutherian species dominant. Man.
Pliocene, in which living Eutherian species occur in a fauna mainly of extinct species.	Living Eutherian species present. Extinct species dominant.
Miocene, in which the alliance between living and extinct Eutheria is more close than in the preceding stage.	No living Eutherian species. Living Eutherian genera appear. Anthropoid apes. Extinct genera dominant.
Oligocene, in which the alliance between extinct and living Eutheria is more close than in the Eocene.	No living Eutherian genera. Living families and orders. Extinct families and orders numerous.
Eocene, in which the Eutheria are represented by living, as well as by extinct, families and orders.	No living Eutherian genera. Living families and orders. Lemuroids. Extinct families and orders dominant.

The most important break in the succession of life-forms occurs at the close of the Oligocene age in Europe and America. From this

[1] Q.J.G.S., pp. 379–404.

break down to the present day the continuity is so marked that we may conclude that the present face of the earth is merely the last in a long succession in the Tertiary Period.

II. The Carboniferous Limestone Zones of N.E. Lancashire. By Albert Wilmore, D.Sc.

THE sequence is well seen in the neighbourhood of Clitheroe, where numerous quarries have been opened up. The lowest beds exposed are near Chatburn Mill, and are dark, thinly-bedded limestones with calcareous shale partings. Fossils are very scarce. There is a great thickness of these almost unfossiliferous beds, the top parts of which are dolomitic.

Bold Venture Quarry, Horrocksford Quarry, and several other exposures show beds in probably lower zone C, with numerous small Zaphrentids (chiefly *Zaphrentis omaliusi*, with the variety *ambigua* of Mr. R. G. Carruthers very common). Higher parts of these beds contain *Caninia cylindrica*, which has been found at Brungerley Bridge, in Bold Venture Quarry, at Pimlico, and at Downham. This species is not so common or well developed as in beds farther east, towards Hellifield and district. Among the Brachiopods are *Chonetes comoides*, *Orthotetes crenistria*, etc. Large Gasteropods such as *Euomphalus pentangulatus* and *Bellerophon cornuarietis* are common. *Conocardium hibernicum* is a characteristic Lamellibranch.

Above these beds come the lowest beds with *Productus sub-lævis*, and the Knoll beds of Coplaw, lower part of Worsaw, etc. Here are the typical zone C, knolls with numerous Brachiopods, the Gasteropods mentioned above, but few Corals. *Amplexus coralloides* is, however, common and *Michelinia* sp.

Above these are well-bedded crinoidal limestones leading up to the knolls of Salt Hill, Bellman Park, Worsaw, etc., which are probably in the upper C or lower S of Dr. Vaughan's zonal scheme. These beds contain a rich Brachiopod fauna, quite distinct, however, from that of Elbolton. Whilst *Productus pustulosus*, *Pr. semireticularis*, *Spirifer striatus*, etc., are quite common, one never finds *Pr. striatus*, *Pr. martini*, and other *D.* forms so common in those eastern knolls.

A fairly rich coral fauna has lately been discovered in these higher Clitheroe knolls; it has not yet been worked out, however. There is probably an unconformity at this level, and then there succeeds a great thickness of shales with limestones, with few fossils. These would appear to be on the same horizon as the richly fossiliferous beds of Elbolton. Above these shales with limestones come the Pendleside limestones, black limestones with cherts, and with irregular bands of more fossiliferous limestone. The Ravensholme limestone appears to be similar and to contain some of the same fauna as the highest limestone at Cracoe and the limestone of the railway quarry at Rylstone described by the writer.

The Bowland shales succeed these beds, and lead up to the Millstone Grit series. A map was exhibited on which some of these generalizations were shown.

REVIEWS.

I.—A Review of Report of the Excavations at Grimes Graves, Weeting, Norfolk. 8vo; pp. 254. Prehistoric Society of East Anglia. London: H. K. Lewis, 1915. Price 5*s.*

THE prehistoric flint mines known as Grimes Graves recently acquired new interest from the suggestion that they might be of Palæolithic age, contemporary with the Cave deposits of England. The fact that this conclusion, if justified, would completely upset all our ideas as to the history of Britain in late Pleistocene time makes it necessary for geologists to take notice of the important work of which this is a review.

Two pits and their associated galleries were almost completely cleared by a committee financially assisted by many institutions and individuals.

The excavations were supervised by Mr. A. E. Peake, who gives an admirably clear account of them, followed by an equally excellent description of the cleared pits and a discussion of the mode of infilling. These diggings, obviously carried out with great skill and care, reveal the following facts, which in the main merely confirm Canon Greenwell's results of forty years ago. The mines consist of shafts, about 30 feet deep, widely funnel-shaped above but with more vertical sides below, of rather accurately circular form, and with a minimum diameter of about 12 and a maximum of about 30 feet. The bottom of the pit is supported by a 'shaft pillar' pierced by about half a dozen galleries which lead into an irregular series of chambers, or perhaps more accurately a general excavation, in which the working faces are so arranged as to leave pillars, as in the pillar and stall method of coal-mining.

The flint worked occurs as a layer of nodules lying on the bed which forms the floor of the galleries. The immense amount of debris from the shaft and galleries was disposed of either by dumping into a neighbouring disused pit, having been hoisted out of the hole by a rope which cut grooves in the side walls at various places, or in later stages by packing it away in disused galleries. The work of excavation was almost entirely performed with picks of red deer antler, whose marks are shown in the chalk, and of which a very large number of broken and worn-out specimens were found in the galleries and fillings.

Some of the cuts in the walls of the galleries were not made by bone picks but by both chipped and ground axes, an observation which confirms Canon Greenwell's discovery of a ground basalt axe in his pit, which has been quite gratuitously questioned. These axes, however, were only used to a slight extent. The flints when extracted were broken up by blows from the back of the picks or from an isolated flint hammer.

Between and round the pits are floors where the blocks of flint were worked up; these are marked by the great mass of scraps and roughly chipped blocks. The animal remains, both mammals and molluscs, belong entirely to living species, and include sheep and oxen, both in all probability domesticated. The articles of human workmanship, except for the red deer antler picks, are described, with a fine series of "minimum shading" line drawings, by Mr. R. A. Smith.

It is an astonishing feature of this lengthy discussion that nowhere is there any indication of the most abundant type of implement found, and that it is largely concerned with rare or unique forms. Working, as this author was, with an enormous mass of refuse from a factory, it is curious that he makes no attempt to discuss the method of manufacture of any type, and that he remarks that "it is to be hoped that 'prehistorians' will no longer countenance the ridiculous notion that the majority of the Grimes Graves flints are nothing but celts in various stages of manufacture". Why such a notion should be ridiculous he does not explain; any personal experience of workshops in countries till recently inhabited by stone-using savages, be it in North America, South Africa, or Australia, will show that an extraordinary lack of finished tools and an enormous abundance of incompletely finished ones, is eminently characteristic of such sites.

Judging solely from the figures and description in this work under review, the commonest type is that which under slightly different forms is represented in figs. 24, 25, 26, 29, 36, 55, 57, 61, 66, 75; this type is also the commonest at Cissbury, judging from specimens in collections. Two other types described by Mr. Smith, represented by figs. 54 (70?) and 74, which are said to be common, must be discussed in connexion with them. No. 54 is a thin, well-chipped blade exactly like the butt of the celt-like form in 24. No. 74 is a thin well-chipped flint with a broad cutting-edge. Both these 'implements' terminate in a slightly oblique fracture. Both are well represented in the Cissbury series at the Manchester Museum, which indeed contains one of each, which fit together and form a single complete celt-like form! That the break in this is an ancient one is shown by the fact that the implement so completed is particoloured, one face of the butt and the other face of the edge being white patinated.

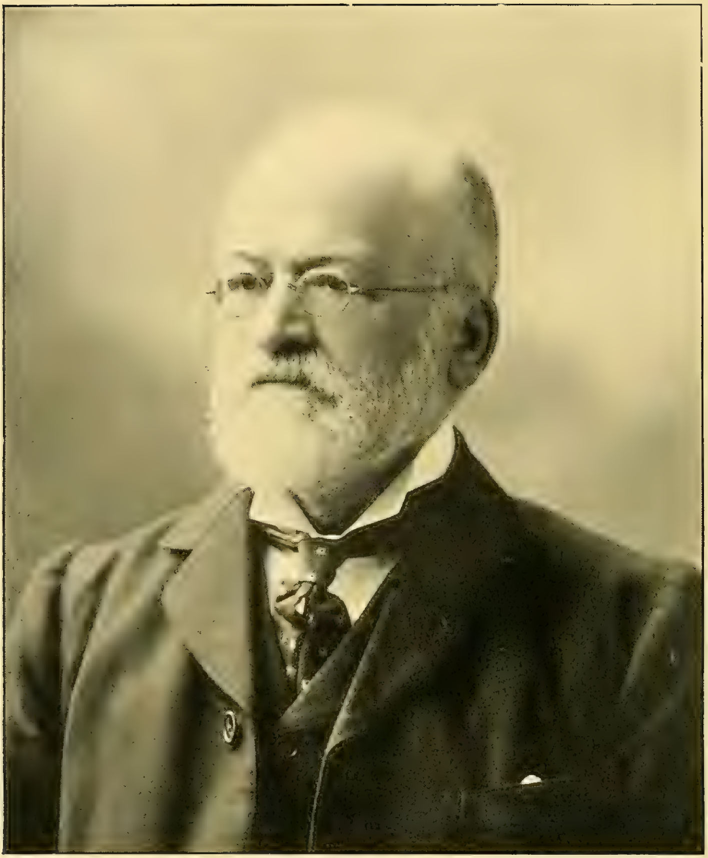
That this implement is not only celt-like, but really is a celt, is certain. Unaltered examples do occur as surface finds in South-Eastern England, and specimens with a variable amount of grinding are not at all uncommon, that vary from axes in which the whole plan of the flaking is quite visible, little but the actual edge being ground, to nearly smooth examples which retain the unsymmetrical section common with rough blanks. Some of the other forms figured by Mr. Smith are of course not celts nor even blanks for their manufacture.

The remarkable specimen, fig. 23, which resembles the tapering portion of a Chelles ficron, is exactly paralleled by a much more remarkable specimen in Manchester, in which the tool is completed beyond the abrupt end of Mr. Smith's example, which is of course nothing but a break, by a thick portion which is ground and polished to the typical segmental edge of a neolithic axe; chipped and polished portions alike are covered by the same white patina.

There seems to be absolutely no escape from the conclusion that these celt-like forms are actually neolithic celts, made as blanks for trade, exported as they stood, and used either rough or after more or less grinding by their 'purchaser'. That such a type of trade is not only possible but probable will be obvious to anyone who will examine in the American Museum of Natural History in New York, or in the Field Museum at Chicago, the immense series of Indian implements which show all stages, from the rough blanks sometimes found in Illinois and Wisconsin in enormous caches of several thousand, to well-finished knives or spear-heads.

Yet in the face of this evidence (which has been available for years) and of the fact that this celt-like form with more or less parallel sides and a segmental edge cannot be matched in cave series, although they are the dominant type at Cissbury and Grimes Graves, Mr. Smith obviously inclines to the idea that the whole series are of an age intermediate between Le Moustiers and Aurignac. This remarkable view is really founded on the occurrence at the Graves (and also at Cissbury) of disc-like flints, very like late Acheulian types and of others resembling 'hand-axes'. The extraordinary implement mentioned above with a neolithic ground axe-head at one end and the point of a Chelles ficron at the other, both obviously of the same age, show that supposititious river-drift type did continue into the age of polished stone. The idea that the industry (for it is obviously only one industry) is of Mousterian age is founded largely on the occurrence of a tortoise core and a couple of flakes of 'Levallois type', a type by the way which was probably not used in later Mousterian time, but surely the great cores of Pressigny are nothing but tortoise cores, rather better made and of post-Palæolithic date? Apart from these the whole argument rests on a series of often unique pieces which may be paralleled in various cave cultures. Argument of this type, the comparison of exceptional tools of one site with exceptional tools of others (of various ages) when the general series are totally different, is surely reducing the study of the cultural stages of stone-using man to an absurdity. Messrs. Mahoney & Kenyon have exhibited in the Melbourne Museum a series of stone tools from modern Australian camps which exactly match the European implement of all the Palæolithic stages placed alongside them; sporadic resemblances of occasional implements to earlier and far removed types are very common; only a few months ago the present writer picked up a typical though small Mousterian point, associated with Indian arrow-heads in Texas.

Mr. Smith asks if the Graves are neolithic, why do we not find polished axes and arrow-heads? Why should we do so? Does the modern flint knapper go to his work accompanied by an axe and a shot-gun? Why should the prehistoric artisan take with him an expensive polished stone axe when a crude unpolished one or a deer horn pick will do his work equally well, and why should he leave arrow-heads, also comparatively expensive, amongst the waste material of his workshop? As these very excavations have shown, polished axes were in existence whilst this industry was flourishing, and until Mr. Smith can produce a polished axe found by a reliable



Dr. CHARLES CALLAWAY.
Died 29th September, 1915.

investigator in an undisturbed cave in a Mousterian layer it is no good adducing stray parallels or evidence of a Palæolithic age for Grimes Graves, and by analogy for Cissbury and Spiennes and other sites. The complete absence of any extinct mammalia or mollusca and the presence of sheep and domesticated oxen are, of course, very strong evidence against a Palæolithic age for this remarkable locality of mining industry.

II.—C. W. Gilmore. A New Restoration of *Stegosaurus*. Proc. U.S. Nat. Museum, vol. xlix, 1915.

In a recent publication (Bull. 89, U.S. Nat. Museum) Mr. Gilmore has given an exhaustive account of the osteology of *Stegosaurus*, and has discussed the various restorations of that curious reptile hitherto published by different authors. In the present paper he gives a new restoration embodying the results of his own researches, and probably representing the nearest approach to accuracy that is likely to be attained. He comes to the conclusion that the large plate-like spines situated along either side of the mid-dorsal line were alternate, not opposite as might have been expected. Furthermore, he believes that the largest spines were not, as is usually represented, situated over the pelvic region, but at the base of the tail, and that the so-called gular ossicles covered the upper surface and sides of the head and neck. The animal probably lived in low swampy ground, and from the proportions of the limbs and some other characters is almost certainly secondarily quadripedal, having been derived from a bipedal ancestry.

OBITUARY.

CHARLES CALLAWAY, M.A., D.Sc.

Born 1838. Died September 29, 1915.

(PLATE XVIII.)

We regret to record the death, in his 77th year, of Dr. Charles Callaway (the well-known Cambrian geologist and a frequent contributor for thirty years to the Geological Magazine), which occurred at his residence, Cheltenham, on September 29. Dr. Callaway was born in Bristol in 1838, and received his preliminary education in that city. Later on his studies were directed to the clerical profession and he entered Cheshunt College, near London, but shortly turned his attention to education and scientific work. He was attracted to geology in early life by collecting some fossils in the Inferior Oolite of Dundry Hill, near Bristol, and acquired practical knowledge of some branches of geology as Curator of the Museum of the Bradford Philosophical Society, as Assistant in Palæontology and Mineralogy in the New York State Museum at Albany, under Professor James Hall, and as Curator of the Sheffield Public Museum. His marriage in 1876 led to his settlement at Wellington, near the Wrekin.

His discovery of an Upper Cambrian fauna at Shineton in shales hitherto regarded as of Caradoc age was the key to most of his subsequent work. Below these shales he found a greenish sandstone, which, by its fossil evidence and its geographic relations, he correlated with the Hollybush Sandstone of the Malvern country, then supposed to be of approximately Middle Cambrian age.

Underlying this sandstone was the Wrekin Quartzite, believed by the earlier geologists to have been metamorphosed by intrusive greenstone forming the core of the Wrekin. Meanwhile Mr. Samuel Allport had been working on the supposed irruptives, and by means of the microscope—which he was one of the first to apply to rock-structures—he proved them to be in the main of volcanic origin, consisting of interbedded ashes and rhyolites. As these strata underlay unconformably a quartzite which was not younger than Middle Cambrian, their Pre-Cambrian age became a fair inference. The subsequent demonstration by Professor Charles Lapworth of the Lower Cambrian age of the Hollybush Sandstone converted the inference into conclusive proof.[1] For this new Pre-Cambrian formation the name 'Uriconian' was proposed.

The granite rocks of the Wrekin were seen to furnish water-worn fragments to Uriconian conglomerates. Thus a second Pre-Cambrian system was recognized. The Pre-Cambrian age of the Longmynd Series also followed from the above discoveries, and the name of 'Longmyndian' was suggested for this great sedimentary formation.

Dr. Callaway extended his researches to the complicated area of Anglesey. He claimed to have proved, after work extending over twenty years, that the Ordovician strata of Northern Anglesey lay in a reflexed syncline, so that the rocks to the north could not be Ordovician, and were probably Archæan; that the crystallines of Northern Anglesey were metamorphosed sediments, that the Grey Gneiss of the southern district was a modified felsite, and that the diorite of the central complex has been modified into an elliptical dome of gneiss. In the Highlands of Scotland he took part in the work which led to the abandonment of the Murchisonian hypothesis. His researches were confirmatory of those of Nicol, but he found that the "igneous rocks" of that author were usually the Hebridean gneiss thrust over the Ordovician (Cambrian) strata by earth-movements—the zone of thrust extending from Loch Erribol on the northern coast to Ullapool. Certain problems in Ireland were investigated. The supposed metamorphic granite of Donegal was shown to be intrusive in the associated schists, the apparent bedding being the result of pressure. In County Galway it was contended that the "metamorphosed conglomerates" and other alleged sediments were plutonic rocks which had sometimes acquired parallel structures under earth-pressures. The district south of Wexford, alleged to show the

[1] In December, 1891, Professor Charles Lapworth described a new species of *Olenellus* which he dedicated to his friend, Mr. Charles Callaway, D.Sc., F.G.S., "who was the first to detect organic remains in the Comley Sandstone, and the first to demonstrate the presence of true Cambrian fossils in Shropshire generally; and whose original and sagacious inferences as to the probable Pre-Cambrian age of the unconformably underlying rocks the discovery of *Olenellus* places beyond much dispute" (p. 532. See GEOL. MAG., December, 1891, pp. 529–36, Pls. XIV and XV).

conversion of sediments into gneisses and schists, was interpreted as a pavement of rocks made up of faulted masses with no gradations between them.

The evidence, acquired in Ireland, that an apparent stratification might be produced in plutonic igneous rocks by regional pressure was subsequently seen to throw light upon the schistose and gneissic masses of Anglesey and Malvern. The gneisses and schists of the Malvern Hills were shown to have acquired their structures under pressure and shearing acting upon a complex of diorites, granites, and felsites. In the area east of the Herefordshire Beacon a second Archæan mass was discovered, which was referred to the Uriconian system. In most of these researches Dr. Callaway received great assistance from the skill and experience of Professor Bonney, who supplied descriptions of large numbers of microscopic sections of rocks.

Dr. Callaway graduated at the London University, B.A. (1862), being third in honours in Logic and Moral Philosophy; M.A. (1863), in Economical and Mental Science; B.Sc. (1872), 1st in Honours in Geology and Palæontology; D.Sc. (1878), in Geology, etc. In 1885 he received the balance of the proceeds of the Wollaston Donation Fund from the Council of the Geological Society, and in 1903 the Murchison Medal. He was made an Honorary and Corresponding Member of the Birmingham Natural History and Philosophical Society, the Liverpool Geological Society, Woolhope Naturalists' Field Club, and Cotteswold Naturalists' Field Club, being President of the last-named club from 1902–4.

Dr. Callaway retired from regular professional work and settled in Cheltenham in 1898. Advancing age rendering the activities of geological research no longer practicable, he reverted to the studies of his early life, and in 1906 he founded the Cheltenham Ethical Society, of which he became the first President. The following are a selection from Dr. Callaway's published papers:—

1874. "On the Occurrence of a Tremadoc Area near the Wrekin": Quart. Journ. Geol. Soc., Proc., March 11.
1877. "On a New Area of Upper Cambrian Rocks in South Shropshire, with a description of a New Fauna": Quart. Journ. Geol. Soc. (Nov.), pp. 652–72.
"The Migration of Species": Geol. Mag. (Oct.), pp. 445–7.
1878. "On the Quartzites of Shropshire": Quart. Journ. Geol. Soc. (Aug.), pp. 754–63.
"The Lower Helderberg Group of New York": Geol. Mag. (June), pp. 271–7.
1879. "The Precambrian Rocks of Shropshire," Part I: Quart. Journ. Geol. Soc. (Nov.), pp. 643–69.
"On Plagioclinal Mountains": Geol. Mag. (May), pp. 216–21.
1880. "On a Second Precambrian Area in the Malvern Hills": Quart. Journ. Geol. Soc. (Nov.), pp. 536–9.
"New points in the Precambrian Geology of Anglesey": Geol. Mag. (March), pp. 117–27.
1881. "The Archæan Geology of Anglesey": Quart. Journ. Geol. Soc. (May), pp. 210–38.
"The Metamorphic and Associated Rocks South of Wexford": Geol. Mag. (Nov.), pp. 494–8.
"The Limestone of Darneo and Assynt": Quart. Journ. Geol. Soc. (May), pp. 239–44.

1882. "The Precambrian Geology of Shropshire," Part II: Quart. Journ. Geol. Soc. (May), pp. 119–25.
1883. "The Age of the Newer Gneissic Rocks of the Northern Highlands": Quart. Journ. Geol. Soc. (Aug.), pp. 535–614.
1884. "The Archæan and Lower Palæozoic Rocks of Anglesey": Quart. Journ. Geol. Soc. (Aug.), pp. 567–83.
"Notes on Progressive Metamorphism": Geol. Mag. (May), pp. 218–24.
"On a new Metamorphic Area in Shropshire": Geol. Mag. (Aug.), pp. 362–6.
1885. "On the Granite and Schistose Rocks of Northern Donegal": Quart. Journ. Geol. Soc. (May), pp. 221–39.
"On Comparative Lithology": Geol. Mag. (June), pp. 258–64.
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L. Richardson.

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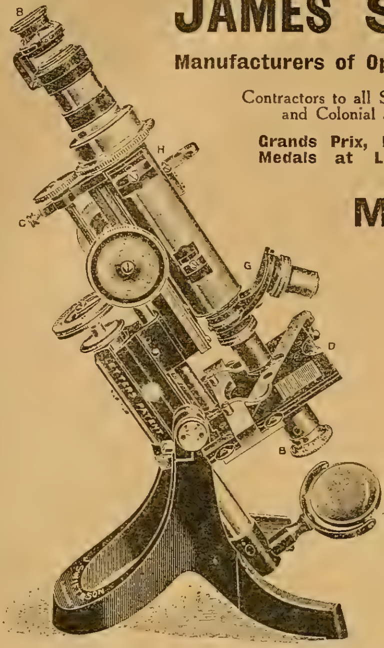

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NEW SERIES. DECADE VI. VOL. II.

No. XII.—DECEMBER, 1915.

ORIGINAL ARTICLES.

I.—The Danbury Gravels.

By Professor J. W. Gregory, D.Sc., F.R.S.

DANBURY stands on a gravel-capped plateau in Mid-Essex, five miles east of Chelmsford. The gravel is part of a once larger sheet and contains a variety of rocks foreign to the district. It was therefore naturally at first regarded as a glacial gravel. This view was adopted by S. V. Wood, jun. (e.g. 1867, p. 12; 1870, p. 61), by the Rev. O. Fisher (1868, p. 98), on the Geological Survey Map (Sheet 1, N.E., 1871), and by Mr. Whitaker (1889, p. 279). Sir Joseph Prestwich regarded the Danbury gravels (1890, p. 135) as Bagshot pebble-beds invaded by some glacial agent, and the late H. B. Woodward (1903, p. 15) described them as the wreck in Glacial times of an older gravel.

Objection has, however, been often taken to the glacial origin of these gravels, as by French (1891, p. 211). They lack the structural features and constituents which in this district are characteristic of glacial deposits. In recent years the conclusion has been widely adopted that these gravels are fluviatile in origin and pre-Glacial in age.

The Danbury gravels lie on a plateau of London Clay at the level of from 300 to 360 feet O.D. They are in situ upon the surface of the plateau at Danbury and on the ridge going north to Little Baddow. They are there exposed in occasional natural outcrops, and in gravel-pits to the south of Danbury Church and to the east of the road to Little Baddow, about a mile north of Danbury Church. Redeposited Danbury gravels occur on the slopes of the Danbury hills; and at still lower levels they are mixed with material from the glacial beds.

The most striking feature of the Danbury gravel is its high proportion of quartzites which are foreign to the district. These quartzites include the liver-coloured saccharoidal variety, pink, yellow, white, and black quartzites, varieties seamed with secondary quartz-veins, some brecciated quartzites, and some which are merely quartzitic sandstones. The series also includes jasperoids which pass into compact red siliceous shales and black cherts.

One of the rarest rocks found in the Danbury gravel is chert from the Lower Greensand, though it is so abundant in the lower level gravels of South-Eastern Essex. Prestwich recorded chert at Danbury (1890, p. 135), and he generally used that term for the Lower Greensand chert; he remarked, however, that it is more abundant in the lower level gravels. Dr. Salter does not record this chert from Danbury, but he has lent me a small pebble he collected from the pit to the south of Danbury, and a section shows that it is a Lower Greensand chert, an identification kindly confirmed by Dr. Hinde. I obtained a larger specimen ($2\frac{1}{2}$ by 2 by 1 inch) from a pit a mile north of Danbury. The Lower Greensand chert is, however, extremely rare in these gravels, whereas in the lower level gravels of Southminster and Southend it forms from 6–14 per cent of the pebbles.

The Danbury gravels have so far yielded none of the felsites or 'rhyolites', which are found in the neighbouring lower level gravels, as I have found them at Gay Bowers, to the south-east of Danbury, at the level of below 200 feet.

Another significant fact in the composition of the Danbury gravels is the absence of Jurassic sandstones and of the large irregular unrolled flint nodules, which are common in the Glacial beds and in the post-Glacial gravels of the district. The Glacial and post-Glacial gravels also contain occasional pebbles of basalt, but I have never found any in the Danbury gravel.

The absence of Jurassic sandstones, large unrolled flints, and basalt indicates that the Danbury gravels were deposited before these rocks were brought into Mid-Essex during Glacial times.

The Danbury gravels are therefore free from the constituents introduced during the glaciation of the district.[1] The structure of the gravels also furnishes no evidence of their glacial origin. The beds are often false-bedded, and they are sometimes contorted and have pebbles standing on end; but I have not seen anything in the gravels which gives clear evidence of ice action.[2] The pebbles are never striated; their forms, though often faceted by wind action, are not those characteristic of the glaciated stones in boulder-clays or glacieluvial gravels; the irregular bedding is of the kind due to rapid currents of water, and the contortions may be explained by slipping down the clay slopes and by movements during the consolidation of the gravel. There appears to be no valid evidence for the glacial origin of the Danbury gravel. It may be objected that such evidence is afforded by the association of boulder-clay with these gravels. The Geological Survey map of the area (Sheet 1, N.E.) does not mark any boulder-clay on the Danbury plateau, but it shows three small patches at lower levels on the adjacent hill-slopes, where they would be associated with redeposited Danbury gravels. I have not, however, been able to find at these localities any boulder-clay or any trace of it. Search for pebbles from the boulder-clay has been in vain. The most probable locality of the three (north-west of Bassetts) has been tested to the depth of two feet by a soil-sampler along a line

[1] My observations fully confirm those of Dr. Salter (1905, p. 31) as to the absence of glacial debris from the Danbury gravels and its presence in the later gravels along the existing river valleys. Wood (1867, p. 2) had remarked the easy recognition of the post-Glacial gravels by the presence of material derived from the Glacial beds.

[2] The eolithically chipped flints which Cunnington called 'glacioliths' indicate the action of severe frost, but not of glacial conditions.

across the middle of the area marked as boulder-clay, but without finding any trace of that material. The stones on this area include no Jurassic sandstones, no large unrolled flint nodules, and no chalk; and the proportions of the stones present, viz. 45 per cent subangular flints, 25 per cent pebbles from the Eocene shingle beds, and 30 per cent of quartz and quartzites, is much the same as in the adjacent redeposited Danbury gravel. The boulder-clay was perhaps marked here owing to the occurrence of some patches of soil which are white owing to the abundance of quartz sand and flint fragments. The boulder-clay in this area is confined to lower levels than the Danbury gravels.

The evidence for the pre-Glacial age of the Danbury gravels does not rest alone on the absence of material derived from the glacial beds. The general physiographic evidence appears conclusive. Glacial beds, including boulder-clay and glacial gravels, are widespread over the Mid-Essex plain at the level of about 200 feet, and they rise gradually north-westward to 300 and 400 feet; but around Chelmsford the boulder-clay does not occur on the higher ground, and the Danbury hills must have stood like an island above the level of the plain on which the boulder-clay was deposited. The main topography of Essex was pre-Glacial. The banks of the river which deposited the Danbury gravels had been cut down into lowland, and a fragment of the bed had been left on the Danbury plateau in pre-Glacial times. The Danbury gravels accordingly date from a period when the relief of Essex was very different from that of the present day. Hence, as the existing topography of Essex was pre-Glacial, and the Danbury gravels were laid down long before its development, the Danbury gravels are very long pre-Glacial.

The determination of a more precise age for these gravels depends on their position and the possible dates of introduction of their constituents. The quartzites and black cherts have probably come directly or indirectly from the Bunter pebble-beds of the Midlands. Some of the gravel heaps in the Midlands, as near Worksop and Nottingham, strikingly resemble those at Danbury owing to the abundance of similar quartzites. I submitted in 1913 a typical collection of Danbury pebbles to Professor Lapworth, Professor Boulton, and Mr. Raw, who agreed that most, though not all of them, could be matched in the Bunter pebble-beds of the Midlands.

If these gravels are not Glacial, then, by whatever route they came from the Midlands, they must have been introduced into Essex at a date earlier than the denudation of the plain, 160 feet lower, which now surrounds the Danbury hills.

Various suggestions have been made as to the route by which the foreign constituents in these gravels reached Central Essex. According to Dr. A. E. Salter (1905, etc.), whose detailed study of the composition of the gravels has thrown most important light on their relations, the non-local constituents came from the west down the Thames Valley or from the north-west across Hertfordshire through the Stevenage Gap. According to others (e.g. H. B. Woodward, 1909, p. 55) these quartzites and old cherts came from the south from the Weald. Prestwich (1890, p. 146) suggested their derivation from

Belgium, and this view received some support from Mr. Clement Reid's adoption (1882, pp. 56–7) of the same source for the non-local pebbles in the Forest Bed gravels.

The solution of this problem may be attempted by the discovery of the original home of the pebbles or by the study of their distribution in Essex. The application of the former method to the quartzites does not promise final results, for these rocks are so very durable that they were widely scattered in Mesozoic and perhaps later conglomerates, so that the determination of the original home of these pebbles may give no indication as to the direction of their last journey.

The study of the quantitative distribution of the foreign pebbles in Essex offers a more reliable method; and it is available in all the constituents of the gravels which were derived from outside Essex. Accordingly, at intervals during many years past I have estimated the percentage of the various pebbles in the chief Essex gravels. The results are shown in the table on pp. 534–5.

This table seems to me to prove the following conclusions:—

1. That the quartzites entered Mid-Essex from the north-west. For the quartzites and pre-Mesozoic cherts are most numerous and the pebbles are largest in the north-west of Essex, and they diminish in number and size to the south-east. Thus they occur to the extent of from 20 to 25 per cent in Danbury, and over 40 per cent near Great Dunmow; but they number only 3 per cent and even less near Burnham and Southminster.

2. That the Lower Greensand chert came from Kent and Surrey: for it is most abundant and occurs in largest pebbles in Southern Essex; it occurs at low levels as far north as Braintree, and even into Suffolk; but in the high-level Danbury gravels it is extremely scarce, and it is absent from North-Western Essex. That this chert was not obtained from the Lower Greensand of Bedfordshire or Cambridgeshire, which is not known to contain it, is further shown by its absence from the gravels in those counties.

3. That a series of felsites [1] (a name that may be conveniently used to cover the various igneous rocks referred to in Dr. Salter's memoir as rhyolite) are widely distributed in North-Western Essex; they are absent from the Danbury gravels, but occur even to the south-east of Danbury in the low-level gravels. According to the evidence collected by Dr. Salter the introduction of these felsites was pre-Glacial.

4. That the Danbury gravels did not contain any material introduced to Essex by ice.

5. That the Danbury gravels contain abundant pebbles derived from the Lower Eocene or Bagshot pebble-beds. The Danbury gravels are therefore later than the Lower or Middle Eocene; and the absence of glacial constituents and their position show that they are pre-Glacial.

The best chance of the determination of a more precise age is given by the distribution of the Lower Greensand cherts. They can only

[1] These felsites are probably derived from Lower Greensand conglomerates in East Anglia or in the adjacent counties.

have been introduced into Essex after the Wealden anticline had been sufficiently raised and denuded for the chert beds to have been exposed on the surface. The Wealden anticline has been often referred to as if due to a single uplift in the Oligocene, Miocene, or Pliocene; thus Prestwich (1890, p. 169) assigned it to the late Pliocene. The uplift, however, was the result of a long gradual movement, which began in the Cretaceous, since the upper zones of the Chalk thin out as they are followed from the Thames Valley southward toward the Weald. The denudation consequent on the uplift had exposed the Upper Greensand by a very early date in the Eocene, since Upper Greensand debris occurs in the Woolwich and Reading Beds (C. Reid, 1896, pp. 493–4). It would therefore not be surprising if the Lower Greensand had also been exposed in the Eocene; but, at the period of Dr. Irving's discussions with Messrs. Monckton and Herries as to the classification of the Bagshot Beds, the presence or absence of Lower Greensand cherts was the accepted test whether certain pebble-beds were Bagshot or redeposited Bagshots. Mr. Bromehead has, however, recently stated (Proc. Geol. Soc., 1913–14, p. 86) that Lower Greensand chert occurs in the upper Bagshot pebble-beds (Bartonian); and if so the Lower Greensand was exposed by the beginning of the Upper Eocene, and the chert from it could have been carried into Essex then or at some later date. Lower Greensand chert appears to be quite absent from the Essex Bagshot Beds, which are clearly much older than the Danbury gravels. Unless the country has been disturbed by differential movements the cherts can only have been carried to Danbury, at the level of 360 feet, from the nearest Lower Greensand outcrops, which are in Kent, some thirty miles to the south, when the Lower Greensand was exposed there at the level of not less than 700 feet above the sea; so that the uplift and denudation of the Weald must have been far advanced before the deposition of the Danbury gravels. The main uplift of the Weald may have been as early as the Oligocene; but it was certainly not later than Miocene, for the Lower Pliocene was a stage of great subsidence, during which the sea spread over the Thames estuary and over the worn-down northern side of the Weald as far south as Lenham and Wye and almost to Folkestone. How far the submergence extended to the west is doubtful; some patches of sand on the Chalk Downs to the south of London have been referred to the Diestian, but on evidence which appears inadequate.

The Lower Greensand chert must have been carried from Kent to Danbury before the Lower Pliocene subsidence. The chert may have been washed into the low-level East Essex gravels at Southminster and Southend in Pliocene or later times, as the slope from the present outcrop of the Lower Greensand cherts near Maidstone would have been sufficient for its transport by river-action into South-Eastern Essex. But it would not have been possible for the river to have carried the Kent cherts on to the top of the now isolated Essex hills at Rayleigh, Langdon, or Danbury, which are as high as the outcrops of chert in Kent, except when the topography of South-Eastern Essex was quite different from the present.

TABLE OF PERCENTAGE

Altitude above Sea. Feet.		Sub-angular Flints.	Eocene Flint Pebbles.	Quartz and Quartzites.
200	Danbury Mission Hall	58	21	21
About 350	1 mile N. of Danbury to E. of road to Little Baddow	{ 53	26	21
		{ 57†	17	25
180–190	Bassetts, Little Baddow (Bamfield) . .	51	27	22
160–170	,, ,, (,,) . .	67	16	17
150	,, ,, (Pear Tree Field) .	45	25	30
About 240	Galleywood, S. of Chelmsford . . .	8½	90½	—
About 240	,, S. of the Church . . .	2	97	1
300	N.E. of Billericay	4	96	0
260	Porters Hall, near Stebbing (N.E. of Great Dunmow)	41	15	42½
370	Langdon Hills	5½	91	3½
About 110	1 mile N. of Witham	35	32	24
180–190	Wickham Bishop	55	15	25
205	Tiptree Heath	58	20	22
100	N.E. of road, 3 furlongs N. of Ulting .	65	20	16
370	Epping Forest; Jack's Hill . . .	20	15	20*
50	Southminster	43	51	·1
Under 50	Burnham-on-Crouch	59	32	3
Under 50	Between Southend and Shoebury Cliff .	53	28	5
—	Walton-on-the-Naze	52–6	23·7	15·2
—	,, ,, ...	20	36	30
—	S.E. of Walton	32	24	26
162	Little Leighs	46*	21	32½
About 160	S. of Braintree (Rural District Com. Pit) .	34½	24½	36½
25	Langford, 1½ m. N.W. of Maldon . .	52·4	21	25
45	Hoe Mill, 1 m. N. of Woodham Walter Church	72	15	12
25	Little Hayes, Crouch Valley, near Rettenden	63	28	4½
—	Cromer Forest Bed Gravels	28·2	20·2	37·6
—	Herts, Gravels of Upper Plain . . .	35		65
—	,, ,, Lower ,, ...	50*	30	20†
278	Horsington, 2 m. S. of Harrow . . .	30	42	10
400–460	Barnet District	20	50	18*
—	Southern Drift from Rochester . . .	60	20	0

[1] The term Brentwood Gravel is used for gravels associated with the Bagshot for those containing much quartzite and usually also abundant Lower Greensand

COMPOSITION OF ESSEX GRAVELS.

Lower Greensand Cherts.		Nature of Gravel.
0		Danbury Gravel.
0	* Including 1 sandstone.	
0	† 2 eoliths and 4 red flints.	
0		
0	No Greensand cherts or Jurassics; 1 large quartzite.	Redeposited Danbury Gravel.
0	(Area marked on Survey Map as Boulder-clay.)	
0	1 Sarsen-stone.	Bagshot Pebble-beds.
0	About ·05 % of liver-coloured quartzite in tiny pebbles ¼" to ½".	,, ,,
0	Brentwood Gravels.	Brentwood Gravels.[1]
0	Felsite, 1½ %.	Braintree Gravels.
0	1 specimen found at this exposure, but elsewhere small fragments of chert common.	,, ,,
9*	* Including ragstone (Prestwich, 1890, p. 132). Typical area of Braintree Gravels.	
—		,, ,, [1]
—		
0	No Jurassics.	
10†	Prestwich. * Including 5 of lydianstone. † Including ragstone.	Westleton Beds of Prestwich. Braintree Gravels.
6		
6	H. B. Woodward and Bennett in Whitaker, 1889, p. 423.	
14		
8·3*	* Recorded as "Chert and sandstone (from Lower Greensand?)" (Whitaker, 1877, Mem. Geol. Surv. Sh. 48 S.E., p. 17).	East Essex Gravel.
14	Prestwich, 1890, p. 128.	
·18	,, ,, p. 129.	
0	* 14 % of large unrolled glacially transported flints; fragments of *Inoceramus*.	Glacial Gravel.
1	Sandstones 3½ %. Felsite present.	
·4	1⅛ % Jurassic sandstones, black jasperoid, basalt, silicified rhyolite, Mesozoic fossils. Palæolithic flakes (not in situ and possibly from soil above the gravels).	Post-Glacial Gravel.
1		
—	Sandstones from Boulder-clay.	
·8	Ironstone 12 %; hard sandstones 8 % (Reid, 1882, pp. 55-6).	
—	Hughes, 1868, p. 283 = 50 % quartz; 10 % quartzite; 5 % jasper, quartzite-conglomerate, etc.	
—	* Including a few bits of ironstone, Jurassic fossils, etc.; † 10 % quartz, 10 % quartzite.	
18†	Prestwich, 1890, p. 137. † Includes ragstone.	
12†	* Includes 3 % lydianstone, etc. (Prestwich, 1890, p. 136).	
20†	Prestwich.	

Pebble-beds and containing no non-Essex material; and the term Braintree Gravels
Cherts, and situated at a lower level than the Danbury Gravels.

The transport of the Lower Greensand chert on to the Essex hills was therefore pre-Diestian, and the Danbury gravels cannot be later than the end of the Miocene.

It may be suggested that Miocene gravels would not have lasted so long in such a situation. But as patches of Bagshot and even older pebble-beds occur in similar positions in the Thames Valley there is nothing very surprising in the survival of a Miocene gravel at Danbury. The Danbury hills owe their existence partly to the slow rate of denudation in a mature low-level country, and partly to the mantle of redeposited gravel on the hill-sides having protected the underlying clay from wind and rain.

The Mid-Essex Fault.—The age of the Danbury gravels is, however, complicated by the possibility that their present elevation may be due to uplift, for if so they might have been laid down in Pliocene times by some southern river, contemporary with that which deposited the Southminster gravels.

If the Danbury gravels stood alone this complication would seriously affect the question, but fortunately the high-level gravels at Rayleigh (alt. 260 feet) also contain Lower Greensand chert; and there is nothing to suggest their differential uplift. As the gravels in the Rayleigh hills must have received their Lower Greensand chert before the Diestian subsidence, the Danbury gravels must have received their scantier supply before that event.

That the Danbury gravels have been upraised by an earth-movement was first suggested by S. V. Wood, jun., who held that a bed of London Clay near Riffhams, to the north of Danbury, which occurs between two beds of the Danbury gravels, owed its position to an overthrust fault. The section is now obscure and overgrown, and in its present condition does not give any evidence in support of Wood's conclusion. The outcrop of the bed is now so weathered that it might be a redeposited clay. But as Wood examined this section when it was clear, and he was not likely to have mistaken rainwash for London Clay in situ, his interpretation of this section is not to be lightly dismissed, especially in view of the fresh evidence for a mid-Kainozoic dislocation along the line indicated by him. Thus the chalk surface under this part of Essex is not a uniform plane, as represented in Geological Survey Horizontal Section, No. 84, 1871; it is disturbed by well-proved irregularities. These irregularities in Mid-Essex are due to a disturbance, which was either a fault or a sharp fold along the line indicated by Wood. Among the evidence for this dislocation is the steep dip in the London Clay at Perry Wood, beside the Kelvedon railway; this dip has been attributed by Holmes to a fault. The Colchester earthquake of 1884 was probably due to a slip on the same or a parallel fault (Meldola, 1885, p. 185). Evidence for differential movement across the Chelmer Valley and for the extension of the fault from Billericay southward to the Thames near Cliff has been recently advanced by Mr. Boswell (1915, pp. 200–2, 205).

The most striking evidence is afforded by the Wickham Bishop bore, which proved that the beds at the base of the London Clay were inverted and repeated. This bore began at 234 feet O.D. and yielded the following section: Soil $1\frac{1}{2}$ feet, drift $41\frac{1}{2}$ feet, London Clay 252 feet, Woolwich and Reading Beds $34\frac{1}{2}$ feet, London Clay repeated $53\frac{1}{2}$ feet, Woolwich and Reading Beds 39 feet, Thanet Sand 56 feet, Chalk 693 feet; total, 1,180 feet.

Dalton (1882, p. 16) attributed this succession to a reversed fault. Mr. T. V. Holmes definitely (1891, pp. 199–200) and Mr. Whitaker doubtfully (1886, pp. 168–9) accepted this view. S. V. Wood (1881, p. 504; 1886, p. 79) referred the disturbance to an S-shaped fold. The difference between a fold or a fault is comparatively immaterial, and this bore strongly supports Wood's conclusion that a powerful post-Eocene dislocation must cross Mid-Essex. This movement, according to Wood & Dalton, was earlier than the high-level gravels at Wickham Bishop; but according to Dr. Salter the movement was later than the gravels, for it uplifted them. The probabilities are in favour of Dr. Salter's view. The age was certainly pre-Glacial and was probably Pliocene. This age is indicated by the following considerations:—

1. The direction of the dislocation is north-east to south-west, and not east to west.

2. The Colchester earthquake shows that the movements along this line have not yet ceased.

3. The Mid-Essex range, which extends from Tiptree through Wickham Bishop, Danbury, and Billericay, was caused by this uplift. The lower Chelmer was already in existence before this uplift, which, being later than the Chelmer, must be much later than the Danbury gravels, since they were deposited before the erosion of the Chelmer and other Mid-Essex river valleys.

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II.—SUGGESTIONS FOR A REVISED CLASSIFICATION OF TRILOBITES.

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(*Concluded from the November Number, p. 496.*)

SUB-ORDER MESONACIDA.

NEVADIA is the earliest and the most primitive member of the Mesonacidæ, and as shown by Walcott[1] may be regarded as representing the ancestral type of this family. The same authority shows that the Paradoxidæ have descended from the Mesonacidæ. *Redlichia*[2] also exhibits features which link it with the Paradoxidæ and the Mesonacidæ.

Beecher[3] places *Zacanthoides* near *Paradoxides*. Woodward[4] suggests that this genus descended from *Holmia*. Walcott[5] couples it with *Albertella* as a member of the Paradoxidæ which exhibits approximations to the Mesonacidæ. Reed[6] agrees with this conception of its affinities. *Zacanthoides* and to a less extent *Albertella* may therefore be regarded as forms which, like *Paradoxides*, have descended from Mesonacidæ. They have, however, attained a more advanced stage in caudalization, a feature which taken with their probable origin from a different section of the Mesonacidæ would justify the formation of a separate family for these two genera, viz. Zacanthoidæ.

[1] Smiths. Misc. Coll., vol. liii, p. 249, 1910.
[2] Walcott, Proc. Wash. Acad. Sci., vol. vii, 1905; op. cit., 1910, p. 254.
[3] Op. cit., 1897, p. 191.
[4] GEOL. MAG., 1902, p. 539.
[5] Op. cit., 1910, p. 254.
[6] *Palæontologia Indica*, ser. xv, vol. vii, p. 9, 1910.

Beecher[1] placed *Remopleurides* alongside *Paradoxides*. If allowance be made for its Aeglinoid type of adaptation to nocturnal habits[2] the similarity of this genus and its allies to the Paradoxidæ and Mesonacidæ is evidenced by such features as the close proximity of the long crescentic eyes to the glabella, the comparatively wide free cheek, the small pleural lobes, and the telson-like pygidium.

These four families—Mesonacidæ, Paradoxidæ, Zacanthoidæ, and Remopleuridæ—thus constitute a compact and natural group forming a sub-order of the Opisthoparia, to which the name Mesonacida may be given. It should be noted that true facial sutures have come into existence within the limits of this sub-order.

In *Marella* the great spines borne by the carapace and possibly the marginal position of the eyes are adaptations to planktonic mode of life.[3] Allowing for this, if the genus 'foreshadows' any one type more than another that type is *Nevadia*, for it possesses a long series of segments apparently without pleural lobes and ending in a telson. On the other hand, *Nathorstia*, as shown by the character of its glabella, the width of the fixed cheek region, and the great size of the pleural lobes in the trunk and tail segments, is a persistent member of the stock which foreshadowed the type of Trilobite represented by *Conocoryphe*, *Ellipsocephalus*, and *Burlingia*. In it, however, caudalization is far advanced for so lowly a form. If with the exception of the tail-region this Trilobite preserves the primeval condition of Trilobites other than Mesonacidæ, the absence of facial sutures in it implies that true sutures have developed independently at least three times, viz. among Mesonacida, among other Opisthoparia, and among Proparia.

Sub-order Conocoryphida.

Conocoryphe and a few other genera which differ slightly from it belong to the family Conocoryphidæ. Beecher,[4] speaking of the Opisthoparia, says, "from a phylogenetic standpoint the family Conocoryphidæ is at the base of this extensive order." Its narrow marginal free cheeks, the diminution anteriorly and clearly marked segmentation of its glabella, the presence of eyelines, the great number of free segments, the micropygous condition, all indicate its primitive character.

Some of the genera included by Beecher in the Conocoryphidæ are now referred to that unwieldy, heterogeneous, and ill-defined family the Olenidæ. Two Lower Cambrian genera belonging to this family call for special attention, viz. *Ptychoparia*[5] and *Protolenus*.[6]

Apart from the presence of eyes the general details of structure of *Ptychoparia* (Fig. 3*d*) are either the same as or progressive developments from those of *Conocoryphe* (Fig. 3*c*). The most marked difference is in the shape and size of the free cheeks. This is due to the shifting of the ocular portion of the facial suture from the margin

[1] Beecher, op. cit., 1897, p. 191.
[2] Cf. Dollo, *La Paléontologie Ethologique*, Bruxelles, 1910, p. 415.
[3] Ibid., p. 409.
[4] Op. cit., 1897, p. 189.
[5] Type species, *Ptychoparia* (*Conocephalites*) *striata*, Emmrich.
[6] G. F. Matthew, Trans. Roy. Soc. Canada, vol. xi, p. 144, 1893.

towards the glabella. The points of intersection of the suture with the margin are the same as in *Conocoryphe*. The posterior one in both genera is quite close to the genal angle, thus causing the free cheek to taper gradually into the genal spine. As to the rest of the body, caudalization has advanced slightly.

Protolenus (Fig. 3*f*), like *Ptychoparia*, evidently arose from a conocoryphid-like stock before the eyes had been lost and before the pygidium had increased to any extent. But these two genera have pursued different lines of development. In *Protolenus* (Fig. 3*f*) the head-shield is wide and short, tending to a tetragonal outline rather than to a semicircular as in *Ptychoparia*. The ocular portion of the facial suture has shifted towards the glabella, but the post-ocular portion has participated in the same movement, so that the point of intersection with the posterior margin is some distance from the genal angle. The free-cheek thus comes to bear a close resemblance to that of the Mesonacida, but the great size of the fixed cheek and the importance of the pleural lobes at once shut it out from that sub-order.

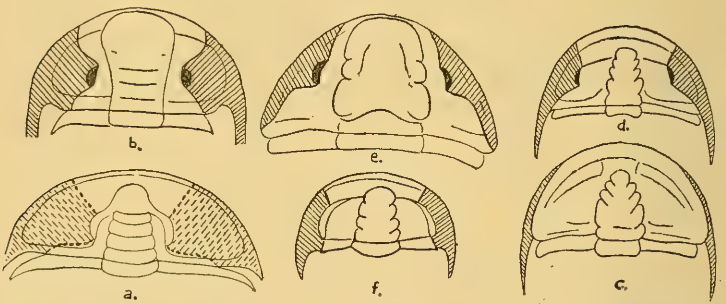


Fig. 3.—Types of Opisthoparian head-shields. *a. Nevadia* (modified after Walcott), dotted and broken lines are hypothetical; *b. Paradoxides*; *c. Conocoryphe*; *d. Ptychoparia striata* (after Barrande); *e. Protolenus* (after Matthew); *f. Calymmene* (after Salter).

These two genera lie near the starting-points of two divergent offshoots of a conocoryphid-like stock.

Protolenus, as its name happily suggests, lies at the base of one offshoot, to which the family name of Olenidæ (s. str.) should be strictly limited. This includes all those genera grouped by Lake [1] into the Continuæ, Abruptæ, and Inermes.

Ptychoparia, on the other hand, is the basal type of a separate group, which may receive the family name of Ptychoparidæ, and which includes *Ptychoparia*, *Protypus*, *Euloma*, *Sao*, *Triarthrus*, *Liostracus*, *Bavarilla*, *Neseuretus*.

In both families the minor modifications, such as the rotation of the pre-ocular suture towards the middle line, the widening of the glabella anteriorly, the smoothing out of the glabellar furrows, pursue parallel courses of development.

[1] Monogr. Palæont. Soc., 1907, p. 51.

Other families group themselves round the Olenidæ (s. str.) and the Ptychoparidæ respectively. In some cases the connexion is close and is evidenced by known transitional forms. In other cases the relationship is distant, and only the inability to find a more suitable place justifies putting them here.

The Proetidæ are a small compact family within which all stages in the increase of free and reduction of fixed cheeks and in caudalization may be seen. Beecher[1] derives them from *Arethusina*, which Reed[2] classes with the Proetidæ and Raymond[3] as one of the Olenidæ. Those features in which this genus differs from the Olenidæ (s. str.) it has in common with *Cyphaspis*. It seems probable, therefore, that the Proetidæ have arisen from an Olenid stock.

In the family Oryctocephalidæ, Raymond[4] includes *Oryctocephalus*, *Zacanthoides*, *Olenoides*, and *Neolenus*. As already seen *Zacanthoides* belongs to the Mesonacida. Reed[5] places *Dorypyge* with *Oryctocephalus* and *Olenoides*. A comparison of these three genera shows that they all possess the *protolenus* type of cheek region. Reed[2] further considers them related to *Parabolina* and *Parabolinella*. But the latter are essentially Upper Cambrian forms in which caudalization has hardly begun. The former are Lower and Middle Cambrian types in which caudalization has already advanced to the isopygous stage. Had the order of appearance in time been reversed close relationship could not have been denied; as it stands, the Oryctocephalidæ must be regarded as a separate branch of the same stock, a branch in which caudalization began early and rapidly reached its acme. Were it not for the spines they might be described as occupying the same position in the economy of the Lower and Middle Cambrian as did the Asaphidæ in the Ordovician.

The Ptychoparidæ, though not so large a family as the Olenidæ, seem to stand near the point of origin of many more families.

The close affinity of the Solenopleuridæ is too evident to call for discussion.

The Dicellocephalidæ include *Crepicephalus* and *Dicellocephalus*. Of the first-named genus Walcott[6] remarks, "the essential elements of the head are generically identical with those of *Ptychoparia striata*, but the pleuræ and thoracic segments and pygidium vary in a marked degree." Certainly the free cheeks are only a slight advance on the ptychoparian owing to the shifting of the ocular suture closer to the glabella and to the posterior margin. *Dicellocephalus* differs from *Crepicephalus* chiefly in being isopygous. The whole family bears the marks suggestive of the adaptation of the ptychoparian type to fossorial habits.

As shown by Pompeckj[7] the Calymmenidæ and the Homalonotidæ are derived from the Ptychoparidæ through *Bavarilla* and *Neseuretus*.

[1] *Amer. Journ. Sci.*, vol. iii, p. 195, 1897.
[2] Op. cit., 1904, p. 74.
[3] Zittel's *Textbook*, 1913, p. 715.
[4] Op. cit., 1913, p. 716.
[5] *Palæontologia Indica*, 1910, p. 10.
[6] *Cambrian Fossils of Yellowstone Park*, Monogr. 32, U.S.G.S., 1899, p. 460.
[7] Op. cit., 1898.

Their predominant peculiarity, viz. the intersection of the facial suture with the margin at the genal angle, is evidently an inherent tendency in the Ptychoparian constitution, for it manifests itself in *Triarthrus*.

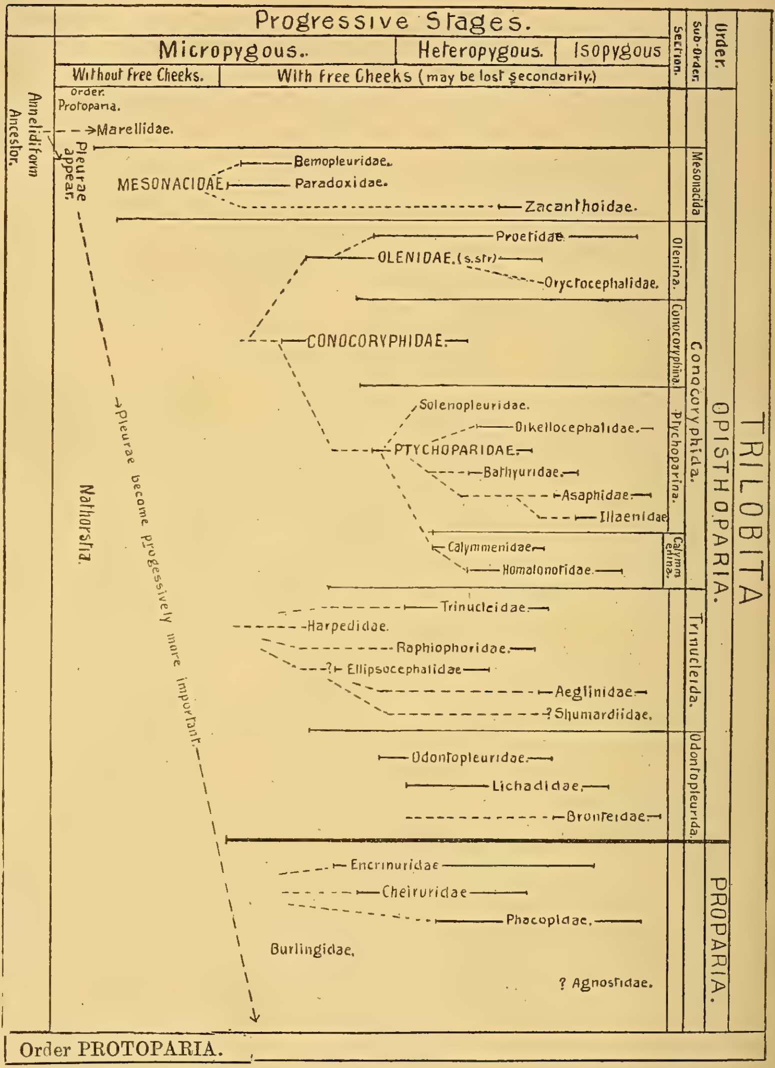


Table showing the main lines of modification which occur amongst Trilobites and the probable general relation of Trilobite families to one another.

Raymond[1] rightly emphasizes the very primitive condition of the Middle Cambrian Asaphid *Ogygiopsis*, and traces from it the main

[1] Trans. Roy. Soc. Canada, ser. III, vol. v, p. 116, 1911.

lines of Asaphid development, one of which culminates in the Illænidæ. Woodward[1] draws attention to the close resemblance of *Bathyuriscus* from the Middle Cambrian to the young of *Ogygiopsis*, a resemblance which proves the Bathyuridæ to be an early offshoot of the ancestral Asaphid stock. Though the requisite connecting links are missing, this stock must probably be looked for among the Ptychoparidæ, for *Bathyuriscus* differs from the latter only in the degree of progressive development such as the broadening of the glabella and axis, the shifting of the ocular portion of the facial suture closer to the glabella, the more advanced caudalization, and concomitant reduction in number of the free segments. The three families, Illænidæ, Asaphidæ, and Bathyuridæ, constitute the isopygous section of the Ptychoparian type. In the more specialized members the post-ocular facial suture shifts away from the genal angle, thus pursuing a course divergent from that seen in the Calymmenidæ and the Homalonotidæ. In every case this is associated with a shifting of the eye, not only towards the glabella, but also towards the posterior margin. This specialization proceeds quickly within the Bathyuridæ and less quickly in the main branches of the Asaphidæ.

All these families whose descent may be traced back to the Conocoryphid type of primitive Trilobite may be placed in the sub-order Conocoryphida, which may be broken into four sections, viz. *Conocoryphina*, *Olenina*, *Ptychoparina*, and *Calymmenina*.

Sub-order Trinucleida.

The three families, Trinucleidæ, Raphiophoridæ, and Harpedidæ, are usually grouped together. The first two closely resemble one another in the short trunk and tail region, with only five or six free segments and the pygidium, which is wider than long. The last is linked on to the first through the Trinucleid genus *Dionide*, which, as shown by Reed,[2] has many points in the head-shield which indicate its intimate relations with *Harpes*, *Harpides*, and *Erinnys*. The remainder of the body, however, retains the primitive micropygous condition with numerous free segments, which decrease in size posteriorly. Here again, however, *Dionide* bridges the gap, for, whilst some species, e.g. *Dionide Richardsoni*,[3] have an almost typically Trinucleid trunk and tail, others, e.g. *Dionide Lapworthi*,[3] are like *Harpes* in outline, and though the pygidium is large show clear indications of numerous segments.

Whilst *Harpes* shows the type of trunk and tail possessed by the ancestral Trinucleid, the characters of the ancestral head-shield[4] must be reconstructed from other genera; thus, *Ampyx* retains its narrow marginal cheeks, *Orometopus* its eyelines and compound eyes, and both show that it did not possess a broad margin or limb, various species of *Tretaspis* and *Ampyx* retain indications of its segmented

[1] Geol. Mag., 1902, p. 532.
[2] Geol. Mag., 1912, p. 202.
[3] *Vide* F. R. C. Reed, Monogr. Palæont. Soc., 1903, pl. iv.
[4] It is conceivable that the absence of facial suture in *Harpes* is a case of retention of protoparian conditions.

glabella. This combination of characters carries the Trinucleid line of descent back to an early Conocoryphid-like stock which had not yet lost the eyes, and in which caudalization had hardly begun. The gap between *Conocoryphe* and known genera is, however, so great that it is necessary to establish a separate sub-order, viz. the Trinucleida.

The Ellipsocephalidæ fail to fulfil the conditions required of the Trinucleid ancestral stock, because their first few segments have already assumed an equality of size, and their remaining free segments, together with the small pygidium, are already shortened to such an extent as to produce an almost Trinucleid shape of body. This similarity to the Trinucleida may be due to parallel adaptation. On the other hand, it is not unreasonable to regard the Ellipsocephalidæ as an early offshoot of the same stock, and therefore subject to the same morphological tendencies as those which characterize the Trinucleida.

Gurich places the Aeglinidæ with the Trinucleidæ. They certainly exhibit the same type of trunk and tail region as that family and the Ellipsocephalidæ. They may be regarded as having the same relationship to the Trinucleida that the Remopleuridæ have to the Mesonacida or, in a less marked degree, *Nileus* to the Asaphidæ, viz. an adaptation to nocturnal pelagic or nektic mode of life.[1]

The Shumardiidæ seem also to possess claims to at least a provisional home among the Trinucleida inasmuch as nearly all their characteristics in head-shield and body shape are paralleled among the members of this sub-order.

These three families—Ellipsocephalidæ, Aeglinidæ, and Shumardiidæ—may be placed provisionally as an appendix to the Trinucleida.

Sub-order Odontopleurida.

Beecher,[2] speaking of the Odontopleuridæ (Acidaspidæ) and the Lichadidæ, says "these two families are closely related". The tendency to develop numerous spines is an adaptation characteristic of planktonic forms. The thinness of the carapace in the latter family is also characteristic of pelagic animals. These features may therefore be left out of account. The usual stability of the glabella in other families and sub-orders emphasizes the genetic and classificatory value of the strong tendency towards the breaking up of the glabella into separate lobes shown in these two families. Apart from this the free cheek in the less modified forms is large and of the Olenid type. There is at present an absence of connecting links between these families and any of the other sub-orders. Until such links are forthcoming a provisional sub-order, the Odontopleurida, may be instituted.

The Bronteidæ (Goldiidæ) present peculiar difficulty, for they are a clearly defined family with no known connecting links with other families. Beecher[3] points out the tendency in some species towards "a breaking up of the glabella into symmetrically disposed separate

[1] Cf. Dollo, *vide supra*.
[2] Op. cit., 1897, p. 197.
[3] Op. cit., p. 196.

lobes as in *Conolichas* and *Acidaspis*". He also draws attention to the reduction of the pygidial axis and extension of the limb as another feature in common with the Lichadidæ. He seems to suggest that the condition in the latter family is a declension from that in the Bronteidæ. But the number of free segments in the trunk is greater and the number of fused segments in the pygidium is smaller in the Lichadidæ than in the Bronteidæ. The difference here, then, is largely a difference in degree of caudalization. The Bronteidæ are not descended from the Lichadidæ, but they carry the Lichadid type of organization along lines parallel to and quite as advanced as some of those which characterized the Asaphidæ, cf. the isopygous condition, the shifting of the eye close to the glabella and to the posterior margin of the head-shield, the union of the facial sutures with one another in front of the glabella. These facts suggest that the Bronteidæ may be provisionally relegated to the sub-order Odontopleurida.

The Proparia.

The order Proparia is not a large one. It includes the families Burlingiidæ, Encrinuridæ, Cheiruridæ, and Phacopidæ. The three last call for no consideration here.

The family Burlingiidæ [1] is of peculiar interest because it carries the Proparia type back from the Tremadocian to the Middle Cambrian. It furnishes a type in which caudalization (Fig. 1*e*), if it has begun, has not advanced beyond the stage seen in the contemporary *Paradoxides*. The great development of the pleural lobes and of the fixed cheeks which extend to the lateral margin of the cephalon removes this family further than the Mesonacida from the primitive annelidan or arthropodan type of trunk. Though so primitive in its trunk and tail regions and in the position of the pre-ocular suture, the relation of the post-ocular suture to the margin shows no sign of approximation to the opisthoparian condition. On the contrary, and in spite of the specialized position of the eye, it is the same as that found in the early stages of development of other Proparia and the highly specialized as well as the primitive Proparian genera. The points of intersection of the facial sutures with the margin in *Burlingia* must therefore be regarded as the primeval positions, and can only have been developed directly from the protoparous condition without the intervention of an opisthoparian stage.

III.—Notes on the North-Western Region of Charnwood Forest.[2]

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

Charnwood Forest, since 1891, the date of the last paper by Canon E. Hill and myself,[3] has been investigated by the Geological Survey. Though part of their map and the accompanying memoir have not yet been published, the general results of their work

[1] C. D. Walcott, Smiths. Misc. Coll., vol. liii, 1908.

[2] Read before the British Association at Manchester, Section C (Geology), September, 1915.

[3] Quart. Journ. Geol. Soc., vol. xlvii, p. 78, 1891.

have been announced by Professor W. W. Watts, by whom most of it was executed. As we stated at the time, we were far from being satisfied with some important points in our own conclusions; so that since my return to Cambridge I have studied my specimens and slices from the north-western region, which had presented to us the more serious difficulties. In 1891 I had been led to regard the characteristic rocks of Peldar Tor and High Sharpley as lava-flows, but considered the dominant rocks of Bardon Hill to be mainly pyroclastic.[1] Professor Watts, however, maintained the intrusive character of the first and second, while taking the same view as myself about the third. The lava-flow hypothesis had appeared to me the more probable, because I doubted whether a mass so large as the Peldar–Bardon porphyroid, if intrusive, could have maintained throughout a texture so uniformly fine-grained, and I had found in the Bardon quarries fragments of it embedded in rock which I then supposed to be a somewhat altered tuff, closely related to the High Sharpley lava. The breccias and the compact rocks of Bardon Hill, the one of which seemed to pass into the other, continued to perplex me, though after repeatedly studying them I became more inclined to regard them as an abnormal result of some kind of flow-brecciation. Having heard how greatly the Bardon Hill quarries had been enlarged, and that others had been opened on Peldar Tor, Canon Hill and I visited them last April and obtained both information and specimens which were very helpful in clearing up difficulties. In July I returned to this district in company with my friend Mr. R. H. Rastall, F.G.S., in order to verify one or two matters and examine a few outlying sections.[2] The specimens collected on these occasions, with those already in my possession, have been carefully studied, and it may be that I have benefited by the widened experience of almost a quarter of a century. The result has been, as I proceed to explain, to convince me that I formerly made the mistake of regarding too large a number of the rocks in the north-western district as pyroclastic in origin.

The Peldar porphyroid is so uniform in its characters, megascopic and microscopic, that it is practically impossible to distinguish specimens got at the Tor from those of Bardon Hill. They have a dull green, slightly rough ground-mass, which, under the microscope, mainly consists of roundish or rather oblong felspars, often about one-thousandth of an inch in length, separated by a filmy yellowish or greenish mineral, in many cases more suggestive of

[1] In our Charnwood papers I accepted all responsibility for the microscopic work.

[2] I gladly tender my thanks to the owners or managers of the quarries—to Mr. B. N. Everard, of Bardon Hall, for giving us the help (as he was himself unable to meet us) of his foreman manager, Mr. R. B. Grant, who personally conducted us over Messrs. Ellis & Everard's quarries and called our attention to particular sections which other geologists had found interesting. The knowledge thus acquired has led him to put aside specimens which strike him as remarkable, and I am indebted to him for two of much importance, which are mentioned in this paper. I have also to thank Mr. J. H. Robinson, of the Peldar Tor quarry, and Mr. J. T. Briers, of the Forest Rock quarry, for much kindly assistance.

a mica than a chlorite. In this ground-mass are scattered crystalline grains of quartz and of a reddish felspar, ranging up to about one quarter of an inch across. But for microscopic details I may refer to what has been already published,[1] as well as for those of the Sharpley porphyroid, which has a rather compact purplish ground-mass. This, under the microscope, is fairly clear with ordinary light, though containing many granules of a dark iron oxide, and with crossed nicols shows a speckled structure, suggestive of devitrification, interspersed by a few tiny felspar laths, probably a plagioclase. In fact, under the microscope, a 'spotty' structure characterizes the one rock, a 'speckly' structure the other. But, as formerly mentioned, the Peldar rock seems occasionally to put on a Sharpley aspect, and the spots in the one, though fairly plain with ordinary light, almost disappear with crossed nicols, as if it might pass into the other.

In 1891 we saw, as already stated, on the more northern side of the middle[2] quarry at Bardon Hill, fragments of the Peldar porphyroid in a rather schistose and brecciated compact purple porphyroid, then supposed to be a volcanic ash, the material of which had a general resemblance to that at Sharpley, and was practically identical with one which occurred in the breccias of Ratchet Hill and of other places in the Forest. Our facts were correct, but not our interpretation of them, as can be most quickly explained by a brief account of our recent observations. In April we saw but little of the compacter purplish porphyroid, the place of which seemed to have been taken by the ordinary greenish rock of the Bardon quarries, but specimens collected prior to 1891 confirm our notes that the former varied from an almost compact rock, indistinguishable from some fragments observed on Ratchet Hill and elsewhere, to a porphyroid only differing from that of Sharpley by its smaller crystals of felspar and quartz. In this rock, to which we then assigned a pyroclastic origin, we found "fragments and possibly lenticular streaks" of the Peldar porphyroid to be fairly common,[3] and in April last we observed similar occurrences in the ordinary Bardon rock, and a sharp junction between masses of the two could be traced at one place both on the floor and in the wall of the pit. We came also to the conclusion that the compact and the brecciated varieties of the Bardon rock passed one into another without any break, and that in the latter the boundaries of the fragments were sometimes not very definite, for in one variety they almost resemble reddish clouds on a dull green ground. Their colour also exhibits the same uncertainty, but the breccias with yellowish-green fragments seem now less abundant than those with

[1] Quart. Journ. Geol. Soc., vol. xxxvi, pp. 342–5, 1880.

[2] Now the fourth, counting upwards from the lowest. The quarry in 1878 was divided into two stages. In 1880 one was opened a little farther down the hill, so the middle quarry of 1891 (Q.J.G.S., vol. xlvii, p. 86) is the lower of our earlier papers. There are now six quarries one above the other, the fourth, counting upwards, corresponding with our 'middle', and two quarries (besides trial holes) on the north-western side, one of them less than 100 feet below the summit (912 feet).

[3] Quart. Journ. Geol. Soc., vol. xlvii, p. 82, 1891.

reddish. The difference also between fragments and matrix is often less marked under the microscope than it appears to the unaided eye, and in some slices it is almost impossible to determine the precise line where the one ends and the other begins. The structure of both occasionally approaches microgranular, but is more often intermediate between the Peldar and the Sharpley types, inclining on the whole to the latter. In fact, the relationship between these porphyroids and the brecciated Bardon rocks has of late impressed me more strongly than ever before. Certain specimens may present characters which seem to be distinctive, but on studying others we find these gradually disappear,[1] the Peldar 'spotting' being interstreaked with a Sharpley 'speckling' as if the two varieties were imperfectly mingled. At the Tor quarry a rather compact purplish porphyroid, like that at Bardon, appears to be intrusive in the Peldar porphyroid, and the former shows by the arrangement of its microliths a slight fluxional structure; but, as in the other locality, the difference between the two porphyroids is more conspicuous to the unaided eye than under the microscope. The compact porphyroid, however, sometimes has a greenish tint, and at Bardon these colour varieties may be seen irregularly interbanded, the one passing into the other. Even the Peldar porphyroid at the Tor quarry sometimes shows a purplish 'bloom'; in fact, I am now convinced that the colour differences in the north-western district largely depend on the subsequent action of water, which has converted some of the more minute constituents into viridite.[2]

The large quarry on Peldar Tor is rudely crescent-shaped, and has been worked back from the road towards the rugged summit of the hill, being carried to a greater depth on its western side. The intrusive compact porphyroid sometimes makes sharp junctions with the Peldar porphyroid, but sometimes partly melts it down, so that the relics of the latter produce a sort of streaking or local mottling in the former. Running obliquely up the wall of the quarry, on its north-western side, is a 'greenstone' dyke, the thickness of which cannot easily be estimated owing to the direction of the section, but perhaps a couple of yards would not be far wrong. It has evidently suffered much from crushing, the effects of which are not nearly so perceptible in the porphyroid. A slice cut at right angles to the shear planes shows under the microscope (1) streaky patches of

[1] Signs of fluxion, as well as of subsequent pressure, may sometimes be noticed, and the former seem to be more common in the neighbourhood of a junction. Many of the Pre-Cambrian and Ordovician felstones, in which some amount of fluxion is perceptible, show, in a single slice, appreciable variations in their microscopic structures.

[2] Viridite is an old term which I think might well be retained. Of course it is vague, but so is the thing thus denoted. It often is obviously made up of tiny flakes, but not seldom has hardly any effect on polarized light (perhaps because they are so minute). Some of the larger flakes appear to be a chlorite, while others have more resemblance to a greenish mica; others may, perhaps, be serpentine. In fact, I believe it to be often more or less of a mixture, varying in composition with the mineral which has been replaced; the above-named colour change from purple to green meaning the formation of a hydrous iron silicate.

viridite, often in very minute flakes, but sometimes large enough to be recognized as a chlorite; (2) rather irregularly outlined scales up to about ·01 inch in length and ·002 inch in thickness, pale green to almost colourless, giving with crossed nicols fairly bright tints and straight extinction, probably a hydrous mica; (3) many grains or granules, with rather irregular outlines, under ·01 inch in diameter, water-clear, and possibly a secondary felspar. In this ground-mass iron oxides, mostly ilmenite, now largely leucoxene, are fairly abundant, in shape rather elongated and irregular. Probably the rock was once a basalt or dolerite. 'Greenstone' dykes are not very rare in the Forest rocks, sometimes in fairly good preservation, but at others so crushed that I once mistook them for slates.[1] Like those at Stewart's Hay, this basic dyke shows the effects of pressure more conspicuously than the rock in which it is intrusive.

The Forest Rock quarry has been opened by the road from Leicester to Whitwick in the southern flank of the Spring Hill moorland, some 300 yards west of the Peldar Tor quarry. It is already a large one with a deeper excavation on the western side of the entry. The dominant rock is a porphyroid, with quartzes[2] and felspars about the size of those at Peldar Tor and Sharpley, in a ground-mass which in colour and texture more resembles the latter; in fact, the specimens remind us now of the one, now of the other. Sometimes, however, the felspars exhibit a roughly parallel arrangement, and the rock then looks more schistose than is usual on Sharpley. This, however, is to a large extent due to a subsequent pressure, which in the part of the pit where it was most conspicuous must have acted roughly at right angles to the direction of fluxion. Both varieties of this porphyroid are associated with a rather compact purplish one, which to the unaided eye resembles those cutting the Peldar rock in the quarries at the Tor and on Bardon Hill. It is distinctly the intruder, sometimes showing a sharp junction and even including fragments, occasionally over a foot across, of the other one, which here and there it has almost digested.[3] Both rocks, but especially the more porphyritic one, contain fragments of the greenish fine-grained speckled rock, so commonly enclosed in the Peldar porphyroid at the other two localities.

In this pit, however, the compact intrusive rock, which to the unaided eye so closely resembles those at Bardon Hill and Peldar Tor, differs from these under the microscope. It has undergone a greater amount of secondary change than one would have anticipated. The felspars, which are the best preserved constituents, form a plexus of laths, in length ranging about ·01 inch, and indicating by their extinction angles a plagioclase near to oligoclase. The intervening ground-mass consists of an iron oxide, brown or

[1] Quart. Journ. Geol. Soc., vol. xxxiii, pp. 785–6, 1877. The mistake is noticed, id., vol. xlvii, p. 91, 1891.

[2] Locally of a reddish colour.

[3] We find sometimes, within 2 or 3 inches of a junction, solitary grains of quartz and half-destroyed felspars, which can only have been derived from the Peldar porphyroid.

brownish red in colour with reflected light, of another which similarly viewed is an earthy grey, sometimes almost white (when it may be leucoxene), and of a minute clear mineral, possibly representing a pyroxene. In this ground-mass larger grains are scattered, also replaced by alteration products, probably once an iron oxide, perhaps ilmenite, and a minute mineral, giving bright tints with crossed nicols, sometimes apparently replacing a felspar.[1] One or two imperfect phenocrystals of that mineral appear in the slice, with a grain of quartz; they are probably, it is almost certainly, derivative. The secondary changes make it difficult to give a name to this rock, but I think it probably a rather basic porphyrite, and that in chemical composition it does not differ so much from the other two as its structure might suggest.

The microscopic structure of the ordinary Bardon Hill rock was described in our papers of 1880 and 1891, so that I need only add that, as stated above, I am now more impressed than formerly by the close resemblance of its matrix, and even of most of the included fragments, to that of the Peldar and Sharpley porphyroids. The fragments, indeed, sometimes exhibit a fairly marked fluxion structure, but the ground-mass of even these seems, with crossed nicols, identical with that which surrounds them. Yet to the naked eye they stand out quite plainly. For instance, in some trial holes above the highest working on Bardon Hill, a variety was obtained which is locally called the 'sultana rock', because reddish spots about as large as those raisins are scattered in the usual dull green ground. But under the microscope we find it very difficult to make out where the one begins and the other ends.

The rock outcropping on the summit of Bardon Hill so much resembles an agglomerate that I formerly felt no doubt of its pyroclastic origin, but my work in the pits lower down made another examination necessary, in which I was aided by Mr. Rastall. The presence of fragments is indubitable, for they project on weathered surfaces from about a quarter to half an inch, subangular to rather rounded in shape, and in diameter from less than an inch to about four inches. They were not, however, quite so large or so numerous as my memory had suggested, being perhaps most abundant in an outcrop, about forty yards from the tower on its eastern side. These fragments, so far as I could see, represented both the 'purple porphyritic' rock and another fairly common in the breccia quarried below.[2] The outcropping masses assume in weathering a rather rounded outline, and one part, a few yards S.S.E. of the tower, faintly suggests a stratification, dipping roughly N.N.E. at an angle rather less than 45°. My friend admitted that a pyroclastic origin seemed to be the more natural interpretation, but after visiting one or two of the pits below he felt obliged to favour the fluxion-breccia hypothesis. A slice from the matrix of a specimen, collected on this occasion, proves that, if we allow for the effects of weathering, it is indistinguishable from the specimens obtained lower down the hill.

[1] In that case it may be a zeolite, but Mr. Rastall suggests to me that some grains more resemble dolomite.

[2] A pale red with dull green spots.

If this rock is an agglomerate, so are they; if they are igneous rocks, so is it; and I am now compelled to abandon the former and adopt the latter conclusion.

This, however, makes it impossible for me to accept the view expressed by my friend Professor Watts in his excellent account of Charnwood Forest.[1] Arguing against our view that the Peldar and Sharpley porphyroids might be lavas, he says that an excavation at Bardon Hill had disclosed porphyroid exactly like that of Peldar Tor, "intrusive into the Bardon rocks. The junction was irregular, the margin of the porphyroid was chilled and fine-grained, and the edge of the Bardon ashes was hardened and turned red."[2] But in 1887, if not earlier, I had examined junctions of the two rocks and had seen, as already stated, lumps of the Peldar porphyroid, a few inches in diameter, completely enclosed in the ordinary Bardon rock.[3] Of these relations I have full notes, written on the spot, and possess a specimen showing a junction of the two rocks. Last July I saw a similar lump of Peldar porphyroid, fully seven inches in diameter, embedded in the ordinary Bardon rock, in which one could detect half-digested remnants of the other.[4] Another large specimen showed, as I had already seen in the quarry, a sharp junction between the two rocks, with no change in the ordinary structure of the porphyroid; which, however, taken as a whole, is not always quite uniform in its texture. Thus, though it may be an intrusive of some kind, a sill or a rather thin laccolite,[5] I am convinced that it is anterior to the Bardon Hill rock.

The second section, quoted by Professor Watts to prove the intrusive character of the Peldar porphyroid, I have not seen, because it was exposed in the excavation for the Blackbrook dam, which was undertaken some time after we had given up work on the Forest. That showed the porphyroid to be intrusive in "rocks of the Blackbrook stage". But as these underlie the Maplewell series, the porphyroid, even if it were a lava at Bardon, might very well be intrusive into them, for its texture, if it be not that of an ancient lava, must, I think, indicate consolidation at no great depth from the surface.

We had not sufficient time at our disposal to examine the whole of that part of Ratchet Hill[6] which we formerly considered to be

[1] *Geology in the Field*, p. 770; also ch. ii in Mem. Geol. Surv., Expl. Sheet 141 (C. Fox-Strangways), p. 5.

[2] Loc. cit., p. 776.

[3] Supposing this to be pyroclastic, I interpreted the other as a fragment ejected in advance of a lava-flow (represented by the Peldar porphyroid); but in any case such a relation makes it in the highest degree improbable for the latter to be the intruder.

[4] For the preservation of this, which (with the second mentioned) is now in the Sedgwick Museum, I have to thank Mr. Grant. The only difference between it and the specimen collected by myself is that the 'Bardon' rock in the one case is greenish, in the other purplish in colour, which, as said above, may be disregarded. Under the microscope they are identical.

[5] I have never detected any hardening of the Bardon rock at the junction with the Peldar porphyroid, and doubt whether the redness mentioned can be interpreted as a contact phenomenon.

[6] A notice of it is given: Q.J.G.S., vol. xxxiii, p. 777, 1877.

pyroclastic and on much the same horizon as the Peldar Tor porphyroid, for a well-grown plantation now occupies the ground. Sharpley porphyroid crops out in the south-east part and is replaced, in going westward, by a breccia,[1] the fragments in which represent the 'purple porphyritic' and the 'syenitoid' mentioned in our notes on the fragmental igneous rocks,[2] and their matrix, indeed the rock as a whole, very closely resembles that on the summit of Bardon Hill. Under the microscope the two are substantially identical. According to my memory (confirmed by my notes) the rock further west becomes more obviously pyroclastic, but until I can re-examine that portion I will say no more than that a rock similar to the ordinary one of Bardon Hill makes its appearance to the west as well as to the south of the porphyroids.

With Mr. Rastall, I once more visited the Swannymote rock. It offers great difficulties, as our former description shows,[3] and some of them have not been removed by the further study of specimens. The occasional mottled aspect of the rock recalls the Bardon Hill breccia, and its microscopic structure bears a close resemblance to that of the Sharpley porphyroid, except that the phenocrystals of quartz and felspar are rather smaller. But how are we to explain the presence of the slate fragments? To the unaided eye they do not appear more altered than those common in other parts of the Forest, and under the microscope they show no sign of contact metamorphism. It has been suggested to me by Dr. Bennett and Dr. Stracey that a variety of the Sharpley porphyroid might have broken through a bed of "slate agglomerate", which can be traced "from the north-east right round the Forest" and "seems to mark a satisfactory horizon";[4] and has swept these fragments along with it. This suggestion deserves very careful consideration, for though the presence of these fragments and their condition seem at first sight strongly in favour of a pyroclastic origin, we may explain the absence of appreciable contact metamorphism by supposing the temperature of the intrusive magma to have been comparatively low.[5] The basalts and dolerites of the Fifeshire coast produce but slight changes in the rocks which they have pierced and sometimes include as fragments. Limestones and dark shales are hardened and the latter changed in colour, becoming a greenish-grey; sandstones are altered to a kind of quartzite, and if red (as in Arran) are bleached, but that is all. They are never even partially melted like the vitrified sandstones of Saxony. The Gross Weilberg basalt in the Siebengebirge contains in its outer part numerous fragments, apparently unchanged, of a trachytic tuff through which it has broken. This explanation seems to me the more probable because I cannot find any other evidence of a pyroclastic origin in the Swannymote rock and am unable to separate its microscopic structure from that of the other porphyroids in this north-western district.

[1] Well exposed in a little ridge running roughly north and south.
[2] Q.J.G.S., vol. xlvii, p. 95, 1891.
[3] Q.J.G.S., vol. xlvii, p. 85, 1891.
[4] *Geology in the Field*, p. 774. Possibly also, they think, the underlying "felsitic agglomerate" may have been similarly treated.
[5] We noticed also that the slate fragments exhibited a rough parallelism.

To conclude: my recent studies in this part of Charnwood Forest have impressed me more strongly than before with the close resemblance of the ground-mass in the porphyroids, the Bardon rock, ordinary and brecciated, and the brecciated rock in the middle part of Ratchet Hill. The fragments also, which occur in the indubitably pyroclastic rocks of the Maplewell series, differ but little from these. They have led me to think that I erred in considering this Bardon rock pyroclastic, to which I may add that of part of Ratchet Hill and perhaps a little more in the north-western district. While the microscope in some cases reveals structures which might well be interpreted as indicative of a pyroclastic origin, these often prove on further examination to be more probably consequences of some kind of flow-brecciation. Besides this, increased experience of the microscopic structure in the ground-mass of the above-named rocks, and in those, such as lavas, where the origin cannot be doubted, have shown me that they can hardly be due to the alteration of volcanic dusts, as I once supposed possible, but that they agree, as said above, with those characteristic of a rather glassy lava, either in the strict sense of that term or as a shallow intrusive. How far their present structure is original and how far due to subsequent devitrification I cannot at present feel quite certain. The devitrification is not so conspicuous as in the old rhyolites of the Wrekin, Pontesford, the Bangor-Llanberis district, St. David's and Boulay Bay (Jersey), and I incline to regarding the microlithic felspar laths mentioned above as original. So the Sharpley rock and its allies may very well have had a vitreous base, but this point must be left for further study.[1] Other volcanic districts, such as Auvergne, the Siebengebirge, and the Phlegræan Fields, prove that lavas varying considerably in texture and chemical composition can be ejected from orifices in one and the same district, and the Lipari Islands show us obsidians, in close proximity to sub-crystalline rhyolites and andesites, and in one case even to rocks which are almost basalts. Indeed, my specimens from these islands, in which subsequent devitrification is improbable, show wider differences than I have observed in Charnwood.

[1] I write this after spending a long time over rock slices from other districts in my collection, and comparing those from Charnwood with others, like them very ancient, in which the structure was less 'blurred' by the formation of secondary minerals, or in which any subsequent change was improbable. There must, no doubt, be some micromineralogical secondary change in the ground-mass, but the main question is, how far that 'spotty' structure of the Peldar rock, which disappears with crossed nicols, is a consequence of this. This disappearance favours an affirmative answer, but I find a generally similar structure exhibited by slices in a (purchased) collection of Hungary rocks, where it must, I think, be primary, and it occurs in a slightly more pronounced state at the Lower Quarry, Enderby (near junctions with a sedimentary rock considered by Mr. A. J. Lowe to be Stockingford Shales), and in the two quarries between Narborough and Croft. But in a slice labelled Thonstein porphyr, Mohorn, near Freiberg, I find a 'spotted' structure which mostly disappears with crossed nicols, and in rock from the Wrekin district, which must have been devitrified, I find indication of a very clear separation of the more felspathic from the more quartzose part, which may be secondary. For a discussion of devitrification, see Quart. Journ. Geol. Soc., vol. lix, p. 440, 1903. So at present I prefer to regard the question as still unsettled.

Another conclusion follows from the above-named close similarity of the ground-masses: that the final consolidation, if the porphyroids are intrusive, not extrusive, rocks, must have taken place within a comparatively short distance from the surface. Hence I believe that the group on the whole is volcanic, and agree with the conclusions as to the history of the district, which were so clearly and succinctly expressed in 1911 by my late friend and old pupil, Mr. A. J. Jukes-Browne.[1]

As this paper has shown, I regretfully admit having made serious mistakes about the origin of some of the Charnwood rocks. First in time is that of supposing the Peldar and Sharpley porphyroids to have been exceptional forms of altered tuffs, and then, after this had been proved erroneous, in supposing the dominant Bardon rock to be pyroclastic. In extenuation I may plead that in 1871, when Canon Hill and I began our work in Charnwood, the microscopic study of rocks was comparatively in its infancy, and that I was misled, prior to the publication of our first paper in 1877, by an eminent foreign petrologist, who had assured me that the porphyroids of the Ardennes were not really igneous rocks (a statement for which I could find no grounds on examining them in 1882[2]). Also, that even ten years later the effect of subsequent pressure on rocks of igneous origin was not so well understood as it is at the present time; and lastly, that even now I have no hesitation in saying that these Charnwood rocks, owing to their exceptional obscurity of structure, due in part to the formation of secondary minerals, are more difficult than any with which I have had to deal in a fairly wide experience. But I have long been convinced that when one has made and published a mistake, it is the wiser course to let this be known, lest it should continue to mislead younger geologists.[3]

IV.—The Carrara, Massa, and Versilia Marble District.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

I. Introductory.

THE range of the Apuan Alps, commonly called the Carrara Mountains, is an offshoot of the Apennines, trending N.N.W. to S.S.E., parallel to the Mediterranean littoral, from which it rises within a distance of barely four miles to a maximum height of 6,000 feet above sea-level. Exclusive of the outer belt of the more recent strata, the Triassic formation, within which the saccharoidal

[1] *Building of the British Isles*, p. 35.

[2] See Proceedings of the Geologists' Association, vol. ix, p. 247.

[3] It is only right to add that, after arriving at the conclusions stated in this paper, I found them to be substantially identical with those already reached by Dr. F. W. Bennett and Dr. B. Stracey, of Leicester. To the one I am indebted for helpful letters and copies of notes communicated to the Geologists' Association, and to the other for kindly lending me some two dozen rock slices from this north-western district, which, having been recently made in Germany, were especially useful as being rather thinner than my own, of English handiwork and for the most part at least a quarter of a century old. It is fortunate that, as now the quarries are being so rapidly enlarged, they and the Forest generally are being watched by such well-qualified observers as these and other Leicester geologists.

marble beds are situated, covers about 25 by 13 kilometres or about 130 square miles, of which the marble zone proper represents 64 square miles or about half. The range is bounded on the north by the Aullela valley in the Lunigiana district;[1] on the east by the Serchio valley in the Garfagnana district; and on the south by the Serchio valley in the Province of Lucca. The marble district, whose western part faces the Mediterranean, comprises the three divisions of Carrara, Massa, and the Versilia in the corresponding parallel valleys of the Carrione, Frigido, and Serravezza Rivers. The Versilia division, which forms part of the Province of Lucca, is composed of the Seravezza, Stazzema, and Arni subdivisions, of which the last-named lies on the eastern watershed of the Apuan range. The Versilia division also includes Pietrasanta, Camajore, Massarosa, and the well-known watering-place of Viareggio, near the last-named of which are situated extensive subaqueous deposits of a peculiarly coarse-grained, sharp macigno sand. These deposits, formed as a delta in a lacustrine expanse by the River Serchio, constitute an important and indispensable adjunct of the marble industry as grinding material for the numerous marble saw-mills in the three parallel valleys already referred to.

Up to 1880 parts of the marble district had been investigated chiefly by Savi, Coquand, Cocchi, and De Stefani, whose views were in part concordant, in part conflicting; but it was only subsequently, in the early 'eighties, that the systematic and comprehensive geological survey of the entire range of the Apuan Alps was carried out by Lotti and Zaccagna, of the Royal Italian Mining and Geological Department, under the direction of Professor Meneghini, of Pisa. This survey was completed in the 'nineties by the publication of the Geological Contour Map of 1 : 25,000 (2·54 inches per mile), together with numerous sections. It was in the period of that survey that the present writer had his professional headquarters in the district for several years, during which he acquired an intimate knowledge of every part of it[2] and had frequent opportunities of discussing and verifying the conclusions of those distinguished geologists.[3] It will, therefore, not be out of place to briefly review the outstanding features of that unique and justly famed district from personal experience and observation.

II. Physiographical Features.

If the range of the Apuan Alps could be reconstructed as it was after its being raised in Miocene times, it would represent a flat

[1] Lunigiana was the ancient Roman Luna district, the Carrara marble being then called Marmor Lunensis. The Apuan Alps were inhabited by a warlike tribe, the Apuani, subdued by the Romans 180 B.C.

[2] In a prize paper, Proc. Inst. Civ. Eng., vol. ciii, 1891, "The Carrara Marble District Railway," the author gave a summary description of the district.

[3] The Memoirs and Notes on the district by Lotti and Zaccagna in the Bollettino del R. Comitato Geologico d'Italia are the following:—

B. Lotti: vol. 1881, pp. 1, 85, 419; and *Carta Geol. d'Italia*, 1910, p. 372.

D. Zaccagna: vol. 1880; vol. 1881, pp. 1, 476; vol. 1896, p. 214.

B. Lotti is now Chief Engineer of the Royal Mining and Geological Department, Rome. Cav. D. Zaccagna is Resident Engineer of the same Department and Director of the Mining Institute of Carrara; he is himself a Carrarese who has, in the words of Dante, "tra bianchi marmi la sua dimora."

ellipsoidal dome whose cupola reached an elevation of over 6,000 feet above sea-level. The initial pressure having been exerted on this part, as indeed on the whole of the Ligurian littoral from the south-west, viz. from the Mediterranean, it is on the side of that littoral that the Apuan Alps are marked by steep and precipitous declivities up to 45 degrees, while on its eastern side they fall away more gradually to the Serchio valley at an average inclination of 20 degrees. Accordingly, denudation and the formation of deeply cut narrow valleys by fluviatile and atmospheric agency proceeded much more rapidly on the western side, which therefore exhibits a series of sharply defined peaks denuded, in their upper parts, of vegetation and imparting to the range its imposing, conspicuously rugged, and Alpine character. On the eastern side, on the other hand, where the process of denudation was less rapid, the mountains, with one or two exceptions, have preserved their dome- or loaf-shaped summit outlines with steep sides, and also more of their original elevation, for it is here that the whole range reaches its maximum altitudes in Monte Pisanino and the neighbouring Monte Tambura. The direction of pressure is also evidenced by the fact that the strata on the western side are much more highly crystalline and resistant than the more fine-grained and softer eastern strata, which, consequently, have been all along the line greatly folded, bent over towards the east, and at many points totally reversed.

The range is thus composed of two series of mountains, viz. of the *pizzi* or peaks of the western, and of the *panie* or loaf-shaped eastern series, the former being about 24 kilometres, the latter about 12 kilometres in length, and the two running, not exactly parallel, but converging towards each other. The natural alignment of the range may therefore be described roughly as that of a two-pronged fork as shown in the plan (Fig. V), the intervening space between the two prongs being occupied by the Arni Valley, about 7 kilometres in greatest width at its upper end. The ends of the two prongs are marked by Monte Sagro (Carrara) on the west and by Monte Pisanino on the east; the junction of the two prongs coincides with Monte Altissimo in the Seravezza division, and the southern end of the fork extends towards Pania della Croce and Monte Forato in the Stazzema division. The altitudes of the principal Western Pizzi and the Eastern Panie, which are marked in the plan, are as follows :—

Western Series, 24 km.		m.	*Eastern Series, 12 km.*	m.	
Carrara	Monte Sagro	1749	Monte Pisanino	1946	Carrara and Massa.[1]
	Pizzo d'Ucello	1782	,, Cavallo	1889	
Massa	Cresta Garnerone	1800	,, Tambura	1890	
	Monte Grondilice	1805	,, Sella	1723	
Seravezza	,, Altissimo	1549	,, Fiocea	1711	Arni.
Stazzema	,, Corchia	1677	,, Sumbra	1765	
	Pania della Croce	1859	,, Freddone	1487	
	Monte Forato	1230	,, Ronchi	1350	

[1] This very conspicuous mountain, one of the highest of the series, is really a *pizzo*, its summit being a ridge not more than 10 yards long and barely 2 feet wide. Monte Forato is, as its name implies, remarkable for the great natural arched opening just below its summit.

The intervening Val d'Arni lies at an altitude of about 1,000 metres at its upper and of 900 metres at its lower end between Altissimo and Sumbra, where the Arni and Freddone torrents join and under the name of Turrite Secca are deflected to the east as tributary of the River Serchio.

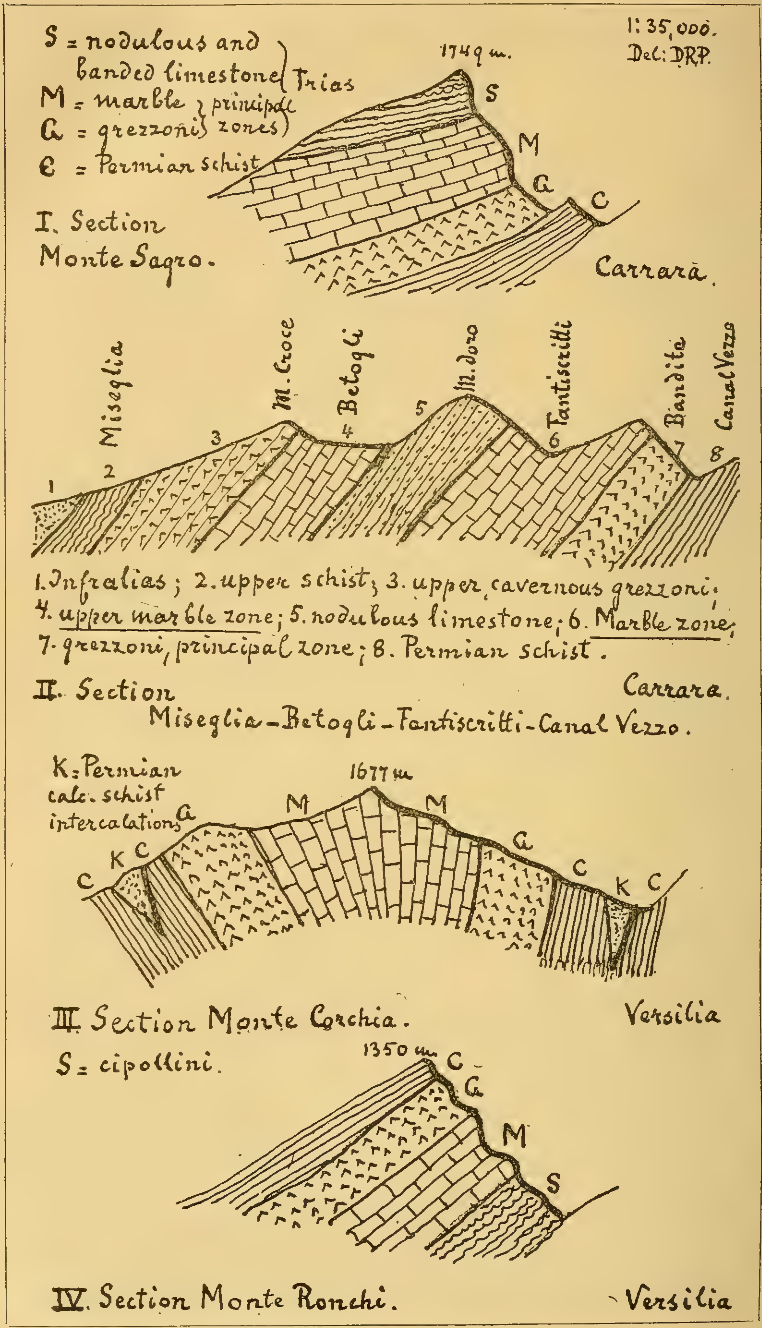
III. The Geological Structure.

The flat, fork-like curves formed by the crest lines of the two series also constitute the direction of the two great anticlinal folds of the range, the intervening Val d'Arni being the corresponding syncline. The two principal folds are not, however, simply uniform anticlines, but are composed of a succession of anticlinal and synclinal flexures which, beginning at the Vinca Pass north of Monte Sagro at the western and at Monte Pisanino at the eastern end, converge and merge into each other near Monte Altissimo and thence extend to the Stazzema end of the range. The extraordinary multiplicity of these flexures renders their co-ordination extremely difficult, the more so as in many of them, notably in the eastern series, the stratigraphical sequence is reversed, while, more especially at their junction near Monte Altissimo, and also near Renara in the Massa division, the strata exhibit extraordinary contortions which only long and patient study and sections of minute detail can unravel. The sections given in Figs. I to IV represent some typical examples, Fig. I showing the normal anticline of Monte Sagro, Fig. II a lower part of the same anticline, with the complete stratigraphical sequence from Miseglia to the Betogli and the Fantiscritti quarries above, viz. north-east of Carrara; Fig. III the normal syncline of Monte Corchia in the Stazzema, and Fig. IV the totally reversed stratigraphical sequence of the contorted flexure of Monte Ronchi in the Arni division, in the junction zone of the two great folds.

All the principal mountains exhibit flexures, more or less accentuated, not only along the precipitous ridges of the crest lines and on the denuded mountain-sides, but in the marble quarries, as well as in the cuttings and tunnels of the Carrara Marble Railway, all of which thus offer a multiplicity of revealing sections. In some isolated cases, where the visible part of a flexure is too acutely bent, there is a rupture of the lowest syncline or of the uppermost anticlinal stratum; but however twisted or reversed the flexures may be, there is throughout the range a total absence of faulting in the sense of fracture or dislocation of the strata. The very fact of the constant succession of normal and abnormal flexures admits of co-ordinating them as components of the two great folds which constitute one of the characteristic features of the range.

IV. The Stratigraphical Sequence.

Proceeding from the Mediterranean littoral upwards into the valleys of the three main divisions, the lower hills, which form the outer fringe of the range about 4 kilometres from the sea, are found to be composed of much folded Eocene alberesi limestone and macigno sandstone, succeeded by Cretaceous and then infra-Lias dolomitic limestone strata. The town of Carrara is built on old alluvial conglomerate resting on those strata. The infra-Lias thence extends



FIGS. I–IV.—Sections of Apuan Alps.

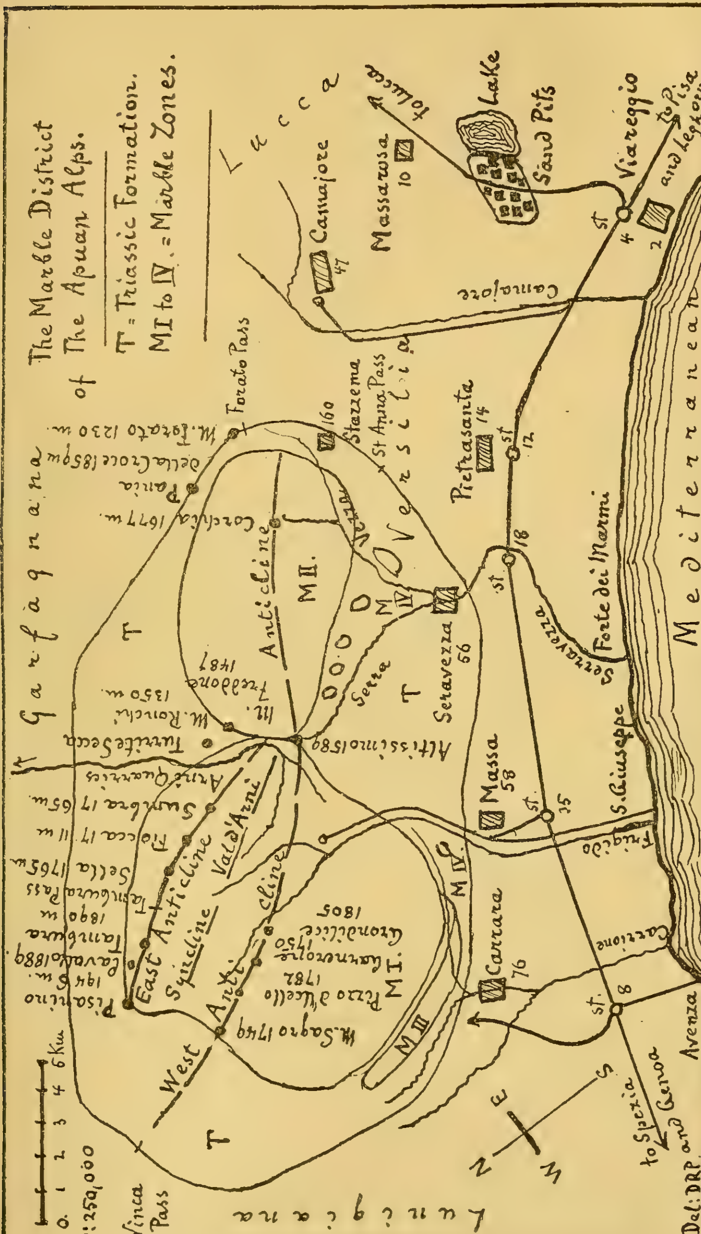


FIG. V.—The Marble District of the Apuan Alps.

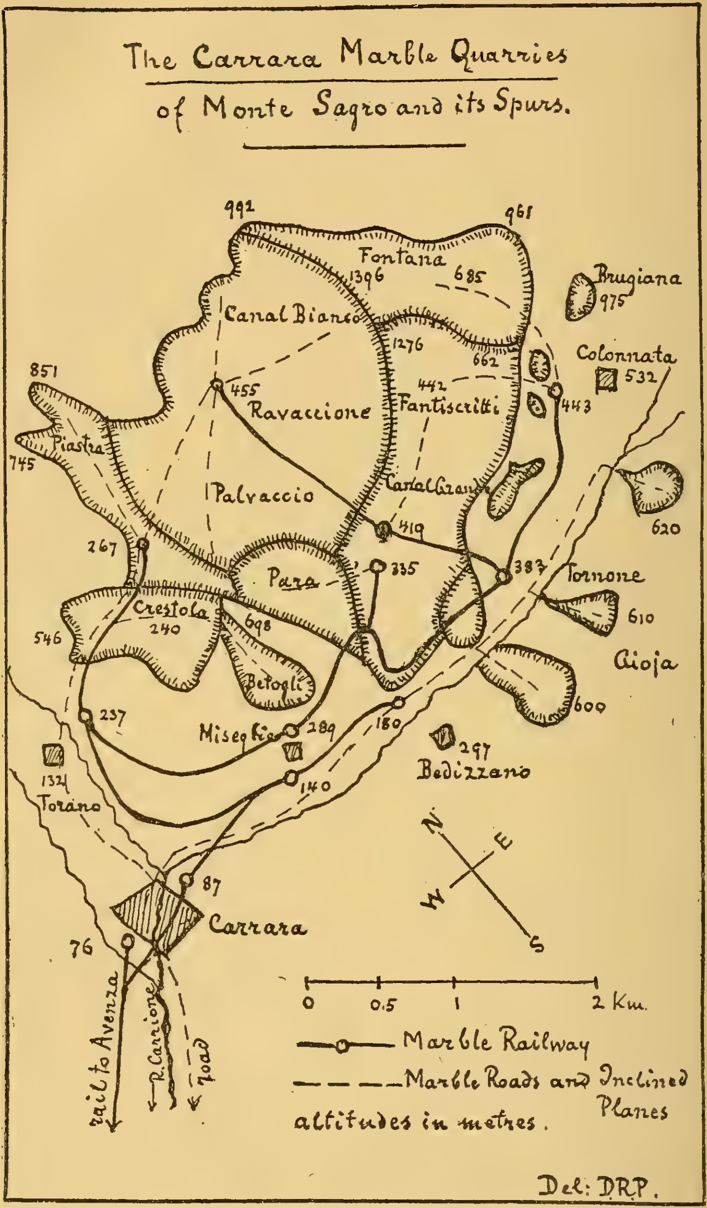


FIG. VI.—The Carrara Marble Quarries, Monte Sagro.

as far as Miseglia, about 1 kilometre north of Carrara, at which point begins the sequence of the Triassic and older rocks. From here, at altitude 240 metres—and about the same level in the other divisions—the succession, omitting the minor alternations—may be summarized as follows:—

		Depth in metres.
MESOZOIC.		
I. Upper Trias.	1. *Upper Schist, Marble, and Limestone Zone.*	
	(*a*) Upper Schist, sericitic and chloritic, with pseudomacigno sandstone . . (*b*) Cipollini and Upper, cavernous Grezzoni, semi-crystalline and dolomitic . .	300
	(*c*) Upper Marble, white, statuary, bardiglio, veined, and breccia	300
	(*d*) Banded and Nodulous Limestone, grey and yellowish	200
	2. *Principal Marble Zone*, white, statuary, bardiglio, veined, and breccia . . .	1,000
II. Middle Trias.[1]	*Principal Grezzoni Zone*, dolomitic, semi-crystalline, dark-grey, brown, and whitish limestone	500
PALÆOZOIC. III. Lower Permian.	*Central Schist Zone*, dark grey, micaceous and gneissose, with calcareous, talcose schist intercalations	1,000
		3,300

It is thus seen that the upper and the principal saccharoidal marble zones together represent a visible depth of no less than 1,300 metres, over three-quarters of a mile. As shown in Figs. I to IV, the normal sequence of strata is uniformly the same throughout the three main divisions of the district, the marble of the principal zone resting normally always on the principal grezzoni beds, and underlying the banded and nodulous limestone of the upper series, except in abnormal or reverse flexures. The strata of the upper series frequently alternate with each other, as shown in Fig. II; hence the marble of that series is always associated with one or more strata of that zone.

V. The Central and the Upper Schists.

The central schists constitute the lowest formation and the nucleus of the range, and round and above them appear concentrically all the successive Triassic series. These central schists were formerly regarded variously as of Archæan, Silurian, or Carboniferous age; but the discovery in 1880 by Lotti and Zaccagna of abundant *Orthoceras* and *Antinocrinus* fossils in the frequent calcareous schist intercalations, notably near Fonte Mosceta in the depression between Monte Corchia and Pania della Croce in the Versilia (Stazzema) division (vide *K* in Fig. III), enabled Professor Meneghini of Pisa to assign the central schist formation definitely to the Palæozoic.[2]

[1] The Lower Trias is, in the Apuan Alps, so sparsely represented by a coarse sedimentary conglomerate underlying the Middle Trias grezzoni at a few isolated points of the range, e.g. near Vinca, Pizzo d'Ucello, and in the Arni region, as to be negligible. The conglomerate marks a transition from Upper Permian to Trias.

[2] "Nuovi Fossili delle Alpi Apuane": Proc. Verb. Soc. Tosc. Scienze Naturali, November 14, 1880.

Subsequently, in 1883 and 1885, Zaccagna, who at that time surveyed both the Grajan and the Western Maritime Alps on the Italian side,[1] showed conclusively that not in the former (nor in the St. Gothard schists), but in the latter is found the analogy with, and the equivalent of, the Apuan central schists, the uniform parallelism of the schists and the overlying grezzoni being in both cases precisely the same. Moreover, the fossils found in the Maritime Alps, notably in the Tanaro valley, were confirmed by Professor Portis[2] of Pisa as indubitably Upper Palæozoic, and hence it is due to Zaccagna that the long debated age of the Apuan central schists was finally determined as Lower Permian.[3]

Between the Permian and the Upper Triassic schists there is a very essential difference. Apart from their totally different stratigraphical position, the Permian schists are distinguished by their dark and predominantly gneissose, the Upper Triassic schists by their lighter, essentially micaceous and lustrous, sericitic texture. On the eastern side of the range, the upper schists often pass into so-called pseudomacigno sandstone; it is only on the western side that they are more crystalline, sericitic, and chloritic, and, owing to minute quartz nodules, sometimes simulate a gneiss-like appearance. In the extremely rare cases where the lower and upper schists appear in juxtaposition, e.g. for a short instance near Canevara in the Frigido valley (Massa), owing, not to any faulting, but to the lenticular thinning out of the normally intermediate strata, they graduate into each other. The Permian schists, moreover, nowhere—except in a similar case of lenticular thinning out in the Arni region—are seen in direct contact with the principal marble zone, whereas the Upper Triassic schists are frequently associated with the marble of the upper and also of the principal zone. This intimate association of all the members of the Triassic series, their constant alternation, thinning out—sometimes completely—and compensating each other, and the consequent absence of faulting, constitute indeed the great characteristic feature of the lenticular structure of that Apuan formation.

The maximum outcrop of the Permian schists occurs in the middle part of the Frigido valley (Massa), whence they extend south-east to the Stazzema division, north-west to Monte Sagro and beyond, and east to Monte Tambura and the Arni region. The Upper Triassic

[1] "Alpi Graje": Boll. R. Com. Geol., 1892, p. 322. "Alpi Occidentali (Marittime)": ibid., 1887, p. 416.

[2] "Piante fossili Valle Tanaro, Alpi Marittime": ibid., 1887, p. 417. The fossils of the Middle Trias grezzoni were determined by De Stefani, P.V.S.T. Sc. Nat., vol. 1880; those of the Upper Trias series by Meneghini, "Fossili Triassici Alpi Apuane": ibid., vol. v, p. 693; and by Canavari, ibid., vol. v, p. 184. Thus, the palæontological evidence of the Apuan Alps is practically complete. The best palæontological and petrological collection of the range, apart from the local one of Carrara, is that of the University of Pisa.

[3] The present writer proposes to deal more fully in a future paper with this Lower Permian formation as distinguished from the Upper Permian verrucano formation. The Permian range of the Maritime Alps forms the divide between Southern Piémont and the Italian Riviera, known as the Montgioje Mountains, where the Tanaro, an affluent of the Po, has its source.

schists, on the other hand, together with cipollini and nodulous limestone, constitute an outer belt, forming, among others, the summits of Sagro, Pisanino, Tambura, Fiocca, and Sumbra, while the rugged crests of Pizzo d'Ucello, Garnerone, and Altissimo are—in the last-named case in a reverse flexure—composed of grezzoni. In the anticlinal folds of Monte Maggiore—a marble spur of Monte Sagro—and of Monte Sella, as well as in the syncline of Monte Corchia, the principal marble zone reaches to the very summits. Pania della Croce, on the other hand, is, in its upper strata, composed of Liassic bluish-grey limestone.

VI. The Marble Beds.

The lenticular marmiferous masses of the Apuan Alps are composed of the four principal groups shown in the sketch-plan (Plate I). The first and largest of these embraces the bulk of the Carrara and Massa, as also the Altissimo, Arni, Sumbra, and Tambura beds. The second group adjoins the first near Monte Altissimo, in the Seravezza division, and thence extends to Monte Corchia and to the end of the Stazzema division. These two groups belong entirely to the principal marble zone directly overlying the Middle Trias grezzoni. The third and fourth groups, on the other hand, belong to the upper marble zone, the third group forming the lenticular mass of Crestola and Betogli in the Carrara division adjoining the principal zone, while the fourth group comprises the smaller, isolated lenticular beds of Monte Rotondo, Trambiserra, Capella, and Costa in the Serra and Vezza valleys of the Seravezza division, as also the outlying Brugiona and Campaccio beds in the Carrara and Massa divisions. The Crestola and Betogli beds of Carrara are separated from the principal marble zone by nodulous and banded limestone; the isolated lenticular masses of the fourth group are all intercalated between the schists, cipollini, and cavernous grezzoni of the upper series.

The varieties and gradations of marble which compose the four groups are substantially the same in all the three divisions. The great bulk of marble is in all cases the ordinary white and highly crystalline, from bianco chiaro (clear white) to the more common yellowish and bluish, representing about 75 per cent of the total, while the statuary proper represents about 10 per cent, and the rest of 15 per cent is made up of the dark and pale blue bardiglio, the blue and violet-veined, and the variegated breccia varieties.[1]

[1] The total annual output of the practically inexhaustible quarries (over 600) of the whole district now reaches 400,000 tons of marble in blocks and for slabs, tiles, ornamental and sculptural purposes, of which Carrara represents about 66, Massa 14, and the Versilia 20 per cent. The 150 saw-mills in the three valleys consume about 130,000 tons of Viareggio sand per annum, almost as much as the total output of sawn marble. The wastage of marble in quarrying and in the other operations amounts to about 10 per cent of the total.

The term "Sicilian Marble" mentioned in a recent paper (Geol. Mag., 1915, p. 290) is not used in the district, much less is it a geological term. It is an obvious and purely commercial misnomer, dating from the time of Napoleon I's embargo on exports to England, when Carrara marble was shipped from Leghorn first to Sicily and thence to England under the above *alias*.

The marble beds of Carrara worked by the Romans are those of Ravaccione, Canal Grande, and Fantiscritti, chiefly for colossal statues, columns, and other

By far the largest proportion of marble in the Carrara division—the principal quarries of which are shown in the plan, Fig. VI—is the common white, the bianco chiaro, and the semi-statuary, the latter being used for colossal statues and columns exposed to the action of the atmosphere.

The finest statuary marble—the *statuario* proper—distinguished alike by its intense cream-colour, its transparency, its homogeneous but not too crystalline grain, its bell-like sound under the hammer, and the ease of being worked with the chisel, occurs only in smaller masses, yielding comparatively small blocks for the finest sculptural purposes. In the Massa division, statuary marble only occurs in one locality, at Bottecini, near Forao, in the Frigido Valley, but the lenticular mass is depreciated by chloritic veins. The ordinary white marble of that division, in the Rosceto and Renara valleys, is less pellucid than that of Carrara, but more fine-grained, and distinguished by its peculiar pearly lustre, albeit with a tendency to become too dolomitic in contact with the underlying grezzoni. It also forms occasional small cavities containing bright quartz crystals known as *stelle*, or stars. To the same category belong the marble beds of the Arni, Sumbra, and Tambura zones, while the great mass of the Monte Altissimo, Giardino, and Falcovaja zone in the Seravezza division is in all respects fully equal to the best ordinary, bianco chiaro, and finest statuary marble of Carrara. Similar to this is the Monte Corchia marble (Fig. III) of the Stazzema division, in which latter also occur considerable masses of fine breccia. The isolated beds of the Seravezza division are all composed of a common, very resistant, bluish-white marble, with occasional dark veins, together with fine blue and veined bardiglio, which equals that of the Para bed of Carrara. Near Colonnata, Carrara, there also occurs a peculiarly black saccharoidal marble associated with the lower grezzoni, the dark colour being probably due to organic impregnations. The *pietra bianca* of Stazzema—as distinguished from marble proper—is a semi-crystalline cipollini variety and, like grezzoni (from *grezzo*, coarse, with rhomboidal fracture), a so-called 'bastard' marble.

Very characteristic is the frequent graduation of ordinary white and bianco chiaro marble into statuary, and vice versa, in the contact and alternation zones of the underlying grezzoni, where rows and patches of so-called *madrimacchie*, or mothermarks, faintly indicate the former lines of stratification obliterated by the action of metamorphism. These brown or ochre marks are obviously impurities infiltrated from the adjoining grezzoni and precipitated by the saccharoidal marble during crystallization, a process which imparted to the statuary marble its high degree of purity. In contact with the overlying nodulous limestone, cavernous grezzoni, or with cipollini, the passage is effected by alternating bands, and the same applies to the contact with bardiglio, which latter alternates with white marble until one or the other predominates. Again, in contact with the

monoliths. The Altissimo quarries and a road of access were opened in 1518 by Michelangelo, whose modest little cottage is still to be seen at Seravezza with the incisive inscription put by himself: "In questa casa abitò Michelangelo Buonarotti per domar le asprezze di questo paese."

upper schists, the white marble shows thin streaks of talcose, lustrous mica, and the same is the case in the veined and breccia varieties. The violet-veined marble called *paonazzi* owes its delicate violet tint to streaks of minute oligist and pyrite crystals. The breccia of the metalliferous Stazzema division also exhibits mineral and micaceous streaks, while the bright-red, wavy marks are due to infiltrations of iron.

Statuary marble, graduating from grezzoni below to ordinary white and bianco chiaro above, occurs in inconsiderable depth more or less in all the principal Carrara quarries from Piastra to Ravaccione, Canal Grande, Fantiscritti, Fontana, Colonnata, and Gioja, while the most abundant and celebrated, because purest and most durable *statuario* occurs in the Polvaccio, Crestola, and Betogli quarries of the Carrara, and in the Altissimo and Falcovaja quarries of the Seravezza divisions.

The most striking and conclusive phenomenon in relation to the statuary marble is that, apart from the lower zones of the marble beds, it occurs also in the very heart of ordinary white marble. This is conspicuously the case in the Polvaccio quarry already mentioned, where the finest *statuario* forms the nucleus of the saccharoidal mass, and gradually passes into ordinary white marble, the latter being here, as the equivalent of madrimacchie, marked by a zone of dusty dark streaks, and hence termed *macchiato*. The intimate association of statuary and ordinary marble is thus conclusively demonstrated.

There is throughout the marble beds in their different varieties and gradations no faulting, nor any evidence of crushing, which, if it existed, would of course render the marble industrially worthless. So far from the marble beds being in any way associated or contemporaneous with the older schists, they form one and all an integral part of the Triassic series which, from the principal grezzoni zone to the upper schists, in stages of metamorphism varying according to the effect of pressure and high temperature upon the original rock material, constitute the lower Mesozoic formation of the Apuan Alps.[1]

REVIEWS.

I.—The Pliocene Mollusca of Great Britain, being Supplementary to S. V. Wood's Monograph of the Crag Mollusca. By F. W. Harmer, F.G.S. Palæontographical Society's Monograph, 4to, 1914, pp. 201–302, pls. xv–xxxii.

In the year 1847 the Palæontographical Society issued its first annual volume, consisting only of Part I of the *Crag Mollusca*,

[1] The evidence adduced in this paper is wholly adverse to the view recently expressed by Professor Bonney in this Magazine (July, 1915, p. 294) that the schists and marbles of Carrara are most probably of Archæan age.

An additional feature of interest in the Apuan Alps is the evidence of former glaciation. Stoppani, as early as 1872, was the first to point out a detritus cone of striated material at the lower end of the Arni Valley (R. Inst. Lomb. Sci. Nat., vol. v, p. 733; also Atti Soc. It. Sci. Nat., Aprile, 1875). Similar deposits occur at high levels in the Carrara valleys and on the slopes of Pisanino, Sumbra, and Corchia; and Zaccagna met with conspicuous *roches moutonnées* on a calcareous schist ledge in the Granolazzo (Upper Serchio) Valley, about 50 metres in length. A more detailed notice of these glacial phenomena would exceed the scope and limit of the present paper.

Univalves, by Mr. S. V. Wood. In the intervening years no fewer than sixty-seven large quarto volumes, rich in illustrations, have gone forth, each containing parts of numerous important monographs, but until the appearance of the sixty-eighth volume the publication of only one author's work has never been repeated. It is a sign of the times, indeed, when this single part represents the total issue of the past year's labours.

The present instalment of this valuable Supplement to Mr. S. V. Wood's *Crag Mollusca* continues the tale of the first part (noticed in the Geological Magazine, 1914, p. 227) and deals with the difficult group of the Pleurotomidæ.

Since the author, as he explains in his preface, has "followed, more or less nearly, for the convenience of students, the arrangement of the Marine Mollusca adopted by him [S. V. Wood]", the new Supplement to the very much earlier monograph, while adding greatly to the value of Mr. Wood's work, will not, we fear, satisfy entirely the more exacting and critical systematists of to-day, despite the manifest care and pains bestowed upon it. No captious criticism, however, can be applied to the plates, which are far and away the best molluscan illustrations the Society has ever published, and impress one at once as being really like the objects they represent, so that altogether the student cannot fail to recognize the forms dealt with, whilst the introduction of figures of recent species for comparison with the fossil forms is a wise and very helpful course, and cannot be too strongly commended to biologists in other groups, whose labours enrich this Society's publications from year to year.

II.—A Description of the Sub-Crag Detritus-Bed. By A. Bell. Proceedings of the Prehistoric Society of East Anglia, vol. ii, pp. 139–48.

THE pursuit of the *ignis fatuus* of pre-Crag Man has not been without some useful results for the palæontologist, since the recent borings have enabled the author of this note to bring together a most useful summary of the latest facts concerning the sub-Crag detritus-bed.

This bed, first brought to the notice of geologists by Professor J. S. Henslow in 1843, is made up of the following constituents: (1) Phosphatic nodules (the so-called Coprolites), (2) sandstone nodules or box-stones, (3) rocks of various ages earlier than the Crag, (4) large chalk flints, many unrolled, (5) rolled and water-worn bones, usually much mineralized, (6) Cetacean beaks (rostra), and other bones, (7) bones and teeth of land mammalia, (8) wood and other items, chiefly of uncertain age. These groups belong to very different periods and are not of equal value numerically. The phosphatic nodules have yielded some twenty species of Chelonia, Pisces, and Crustacea, all of Sheppey types. The box-stones, the author considers, present in their fauna hardly any elements in common with the Diestian, to which they have been referred. The list of fossils contains eighty species of the more characteristic shells of the Oligocenes of North Germany, Belgium, and Denmark, but the facies suggest to Mr. Bell a later date, somewhat nearer Miocene times.

How some of the rocks came into the area is an unsolved question, as also the exact type and horizon of the flints. The age of the rolled and mineralized bones, both of whales and land mammalia, whether Pliocene or Miocene, is still considered doubtful, and the author concludes by damning with faint praise the alleged pre-Crag occurrence of Man.

III.—A Contribution to the Knowledge of the extinct Sirenian *Desmostylus hesperus*, Marsh. By O. P. Hay. Proc. U.S. Nat. Mus., vol. xlix, p. 381, pls. lvi–viii.

THE remarkable Sirenian which forms the subject of this paper was originally described in 1888 by Marsh, who with very fragmentary material at his disposal was nevertheless able to determine its affinities with accuracy, as is clearly proved by the specimen now discussed. This consists of the greater part of a skull wanting a portion of the snout and some other parts. Some of the peculiar teeth are *in situ*. The skull differs from the usual Sirenian type (1) in having the snout only slightly deflected and (2) in having the narial opening comparatively small and far in advance of the orbits. The teeth are extremely hypsodont, and are composed of rows of cylindrical columns closely crowded together. Their peculiar character led Yoshiwara and Iwasaki, who described a closely allied but larger species from Japan, to regard the animal as probably Proboscidean. The two species, *Desmostylus hesperus*, Marsh, from the Western States of America, and *D. watasei*, Hay, from Japan, are of Miocene age.

IV.—The Fauna and Stratigraphy of the Kent Coal-field.

MR. HERBERT BOLTON has recently issued a paper on the above subject (Trans. Instit. Mining Engineers, vol. xlix, pp. 643–702, pls. vii–ix, 1915), which had been previously read before the Manchester Geological and Mining Society. His researches contain the results of an examination of a large series of Coal-measure cores from the Kent Coal-field, obtained from localities lying within "a triangular area, bounded by the coast-line from Dover to Ramsgate on the east, by the Dover to Canterbury road on the south, and by the railway line from Canterbury to Ramsgate on the north". The Carboniferous Limestone floor was reached at depths varying from 3,185 feet at Bourne to 1,149 feet at Ebbsfleet, whereas the Coal-measures were proved to exist in other parts of the region investigated at considerable depths without striking the Carboniferous Limestone, as for instance at Maydensole, where they were pierced at 3,512 feet below Ordnance Datum. The author gives important generalized sections of all the borings undertaken, including carefully determined fossils found in each, with ample notes on the species, the whole fauna being tabulated for comparison with that of the Somerset and Bristol Coal-fields. He refers to a difference of opinion between himself and Dr. Arber as to the presence or otherwise of

Lower Coal-measures in the Kent Coal-field. From his studies of the fossil flora of the region, Dr. Arber has been unable to recognize the existence of the older Coal-measure Series, whereas the author states that the occurrence of *Lingula*, *Orbiculoidea*, and *Productus* conclusively proves the opposite view, he being also of opinion that a fauna furnishes more reliable data as "determinants of the age of the beds" than the flora. The palæontological evidence is considered to support Marcel Bertrand's theory "of a formerly continuous coal-field stretching from South Wales on the west, through Bristol and Somerset into Kent, and thence eastwards to the Pas-de-Calais of Northern France and Belgium". A plate of fossils and diagrammatic sections of the various borings add to the great interest of the memoir, among the former being illustrations of *Prestwichia anthrax*, different forms of *Anthracomya*, *Naiadites carinata*, *Lingula mytiloides*, *Orbiculoidea nitida*, *Productus scabriculus*, *Cœlacanthus elegans*, etc.

R. B. N.

V.—A peculiar Oolite from Bethlehem, Pennsylvania. By Edgar T. Wherry. Proc. U.S. Nat. Mus., vol. xlix, pp. 153–6, pls. xl, xli, 1915.

THE oolite described occurs in magnesian limestone of Upper Cambrian age, and is chiefly remarkable for the fact that, except in the centre of the blocks formed by bedding and joint-planes, the grains are divided equatorially into upper light and lower dark portions. They are composed of dolomite of purer consistency than the matrix, and the darkness of the lower halves is due to carbonaceous matter.

The author's explanation is as follows:—"When the ooids [oolitic grains] were first formed they no doubt consisted of aragonite, whereas the matrix was dolomite-mud. Mixed with the aragonite, in varying amounts in the different concentric layers, was the carbonaceous pigment. After the solidification of the sediment into rock and the development of joint cracks (but before the uptilting of the beds) waters penetrated along these cracks and along the bedding planes. Since aragonite is more soluble than the dolomite of the matrix, it dissolved away, leaving behind the carbon and the nuclei—sand grains and bits of kaolin—in some cases stripped of all concentrically deposited aragonite, in others still retaining a few layers. These settled to the bottom of the cavities in heaps, the shapes of which varied with the sizes of the nuclei and the stage of solution process at which they fell into the masses of carbon powder.

"At some later period water again traversed the rock, but this time conditions were favourable to deposition instead of solution, and secondary dolomite filled up all openings in the rock, tension and joint cracks as well as the holes left by the removal of the ooids . . . The secondary crystallization took place so slowly and quietly that the heaps of carbonaceous dust were not disturbed, but merely enclosed by the crystal grains, and their shapes preserved."

VI.—FAUNA OF THE WEWOKA FORMATION OF OKLAHOMA. By GEORGE H. GIRTY. Bulletin 544, Department of the Interior United States Geological Survey (George Otis Smith, Director), 1915. pp. 353, with 35 plates.

IN this memoir the author makes some interesting preliminary remarks on the duties of the palæontologist, whom he regards as a biologist and a stratigrapher. He states that "the stratigraphic palæontologist, or, as he might be called, the stratilogist, is not primarily concerned with the delineation of geologic formations on a map . . . his special task is the correlation of formations that are geographically separated". He is of opinion that a fauna should be fully described and figured, and not listed as is often done, which is "in effect to state conclusions without producing evidence". The Wewoka formation belongs to the Carboniferous system, its faunistic facies suggesting an early stage of the Pennsylvanian series as well as exhibiting some striking resemblances to certain fossils from Kansas of about the horizon of the Fort Scott Limestone. Most of the zoological groups are represented in this fauna, the Mollusca being numerically greater than the Brachiopoda. The Foraminifera (*Fusulina*), Sponges, and Crinoidea are more or less rare, whereas among the Corals *Lophophyllum profundum* is said to be of abundant occurrence. Nearly 150 species or forms are described and figured, an account of the more important genera being also added. The work has been carefully prepared, and is a valuable addition to the history of an extremely interesting Palæozoic fauna.

R. B. N.

VII.—FAUNA OF THE SAN PABLO GROUP OF MIDDLE CALIFORNIA. By BRUCE L. CLARK. Bull. Dept. Geol. Univ. California Public, 1915, vol. viii, No. 22, pp. 385–572, pls. xlii–lxx (chiefly Mollusca) and pl. lxxi (map).

THE author's researches on this series of Tertiary rocks have resulted in the San Pablo Beds being recognized as a 'group' rather than a 'formation' as originally described by Professor J. C. Merriam, and representative of the Middle Neocene. From a study of the fauna, the San Pablo group of Middle California is made divisible into two major zones which are quite distinct, as shown by the molluscs and echinoderms, both zones being again split up into minor faunal zones, which are indicated by the restricted range of echinoderm species, as also of molluscan species. Although mostly of marine origin, it is ascertained that the San Pablo deposits exhibit at different levels certain estuarine and brackish-water conditions. Many of the extinct species are related to forms living off the present-day Californian coast (= Pacific). The author is further of opinion that the San Pablo group is of Upper Miocene age.

The described fauna includes 9 extinct species of Echinodermata; 3 Bryozoa; 3 Crustacea; 86 Pelecypoda, of which 55 are extinct, 27 recent, and 29 new; 62 Gastropoda, embracing 46 extinct, 9 recent, and 33 new; and 1 Scaphopoda. This memoir is planned out with great care and detail, every information being given in connexion with the stratigraphy and lithology as observed at the various localities, together with well drawn up faunal lists. Correlation data, a bibliography, and well-executed plates stamp the whole work as a contribution of considerable importance to our knowledge of Californian Tertiary palæontology.

R. B. N.

VIII.—Brachiopod Genera: the Position of Shells with Magaselliform Loops, and of Shells with Bouchardiform Beak Characters. By J. Allan Thomson. Trans. New Zealand Inst. 1914–15, vol. xlvii, pp. 392–403, with text illustrations.

As indicated by the title, this paper deals with the evolutionary characters as observed in the loop and hinge structures of certain Brachiopod shells. The Terebratelliform type is discussed with special reference to *Terebratella sanguinea* of Recent seas. Then follow remarks on the Pachymagoid and Neothyroid types, illustrations being given of the cardinal process in *Pachymagas parki* (Hutton), *P. huttoni*, sp. nov., *Neothyris ovalis* (Hutton), all from the New Zealand Tertiaries; and *Neothyris lenticularis* (Desh.) of recent habitat. The author then describes the new Miocene genus *Magella*, which possesses a Terebratelliform hinge and a Magaselliform loop, based on what he formerly determined as *Terebratella kakuiensis*, but which on account of the specific name being preoccupied is now changed to *Magella carinata*. Shells with Bouchardiform beak characters are next discussed, there being certain New Zealand Miocene (Oamaruian) forms described by Hutton, as *Bouchardia rhizoida* and *B. tapirina*, which while possessing Bouchardiform beaks are furnished with Magellaniform loops and septa; for the reception of such the author proposes the new genus *Rhizothyris*, the selected genotype of which is Hutton's *Bouchardia rhizoida*. Some shells are said to be provided both with Magaselliform and Terebratelliform loops, but showing Bouchardiform beak characters and contour, and for these is established the new genus and species *Magadina browni*, from the Mount Brown Beds of North Canterbury. Another new genus is described as *Magadinella* on Tate's type of *Magasella woodsiana*, in which the beak characters are not strictly Bouchardiform, although bearing considerable external resemblance to *Magadina*, but with a more advanced loop structure than that genus and representing an early Terebratelliform stage.

R. B. N.

IX.—Revision of the Tertiary Mollusca of New Zealand, based on Type-material. Part II. By Henry Suter. Palæontological Bulletin, No. 3, New Zealand Geological Survey (P. G. Morgan, Director). 4to; pp. 69, with 9 plates, a transmittal letter by P. G. Morgan, and a preface by Henry Suter. Wellington, 1915.

The first part of this monograph, which was issued last year and of which a review has already appeared (Geol. Mag. 1915, pp. 374–5), comprised a revision of the molluscan species described in the late Captain F. W. Hutton's *Catalogue of the Tertiary*

Mollusca and Echinodermata of New Zealand in the Collection of the Colonial Museum, published in 1873. The present fasciculus embraces further revision work of New Zealand Tertiary shells described subsequently to 1873 by the same author, and which are said to be preserved in the Canterbury, Otago, and Geological Survey Museums. Mr. Suter also furnishes redescriptions of six species of the Hutton Catalogue, besides including some notes on other molluscan types established by Kirk, Hector, E. de C. Clarke, P. Marshall, and J. Allan Thomson. He recognizes rather more than a hundred species of Gastropoda and about forty Pelecypoda, among them being the following new forms: *Struthiolaria parva*, *Turris* (*Hemipleurotoma*) *nexilis*, Hutton, sub-species *bicarinatus*, and *Trigonia neozelanica*. The whole of the species, as in part i, belong to rocks which are regarded as either of Miocene or Pliocene age. As this completes the author's researches on the type-material of New Zealand Tertiary Mollusca, we heartily commend its results to all students of palæoconchology, as well as to those interested in problems connected with the ancestry of present-day shells common to New Zealand seas.

R. B. N.

REPORTS AND PROCEEDINGS.

I.—Geological Society of Glasgow.

At the first meeting of the session of the Geological Society of Glasgow, held on October 14, Professor J. W. Gregory, F.R.S., F.G.S., delivered his Presidential Address on "Geological Factors affecting the Strategy of the War".

The following summary has been issued:—

The geological influences on international politics are less widely appreciated than the geographical, but the War with its new struggles on former battlefields is largely controlled by the geological structure of Europe. The distribution of the mineral resources of the Continent is affecting the course of the War, and may have a still more important bearing on the diplomatic negotiations at its end. The redistribution of political power in Europe during the past forty years has been greatly affected by the discovery that Germany is one of the greatest coal countries of the world. Since 1870 we have increased our coal output two and a half times, and Germany has magnified hers eightfold; and even more significant is the discovery that the German coal reserves are estimated as more than twice as large as our own, and are estimated as 423,000 million tons, out of the 784,000 million tons for the whole of Europe. The significance of that pregnant fact has not been generally recognized. The German coal-fields are all placed in exposed positions near the frontiers, and Germany has therefore maintained an army ready for instant battle. Her military capacity has been illustrated by her seizure of the Belgian, Polish, and chief French coal-fields and successful defence of all her own.

The future of the war-wrecked Galician oil-field affects British interests in opposite ways. The Scottish oil trade would profit if the field were annexed by Russia; but those British industries which need cheap paraffin would suffer by the change. The belief that Germany could not continue the struggle if her imports of copper were stopped was one of the most widespread early illusions of the war. Germany's own copper production would doubtless suffice for her military needs. The total copper production of Germany in 1913 was 25,000 tons, but with a rise in the price of copper the extensive areas of low-grade ores at Mansfeld could be profitably worked.

The great iron ore-field of Lorraine and the recent discovery of the potash mines of Alsace both increase the difficulty of the readjustment of the Franco-German frontier. Germany now obtains three-quarters of her iron-ore from Lorraine and would strenuously resist the loss of that field. The transfer of that area would probably be detrimental to its own economic interests. The re-annexation of Alsace by France offers the best prospect by breaking the German monopoly in the supply of potash. The Americans especially have endeavoured to escape from that monopoly by finding fresh sources of potash and by dodging German restrictions on the output. The German potash fields were formed by such an unusual sequence of geographical events that they are quite unique. It has been calculated that one of the German fields, even with an increased output, will last for 600,000 years. It has been suggested that at the end of the war the German potash mines might be held as security, but they are so widely spread through Western Germany that their military occupation would be very expensive and the total profit from the potash mines would be insignificant in war finance.

II.—Liverpool Geological Society.

The annual meeting of this Society was held on October 19, 1915, the President, Mr. W. A. Whitehead, B.Sc., in the chair. Mr. J. H. Milton, F.G.S., F.L.S., was elected President for the new session, and Dr. J. C. M. Given Vice-President. It is gratifying to record that the Society enters upon its fifty-seventh session with a slightly increased membership and with undiminished vitality.

The retiring President took for the subject of his address "Sandbanks and Sand-dunes". The conditions affecting their formation and growth were discussed in detail, special reference being made to the deposits of the Lancashire coast, which extend twelve miles north of Liverpool and eight miles out to sea. Surface features such as ripple and current marks were then described, and the differences between æolian and subaqueous ripple-marks explained. Finally, the records in the Triassic sandstones were referred to, and compared with the modern deposits. Ripple-marking was a fairly common feature in certain beds of the Trias, and was mostly associated with marl bands, and presumably with shallow water, judging from the proportions of length to height. In fact, most of the positive evidence pointed to local water conditions, and it was not impossible that as more was discovered about the building of dunes and sand-banks, geologists might be able to decide on inspection whether a false-bedded section represented an æolian or an aqueous deposit.

III.—Geological Society of London.

November 3, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

Dr. C. W. Andrews, F.R.S., gave an account of the discovery and excavation of a very large specimen of *Elephas antiquus* near Chatham. The specimen was originally discovered about three years ago by a party of sappers who were digging a trench. The attention of the British Museum was drawn to this find by Mr. S. Turner, of Luton, Chatham. The extraction of the bones was delayed until the past summer. A great part of the skeleton has now been collected, owing largely to the skill of Mr. L. E. Parsons, jun. The skull, unfortunately, was in a very bad condition, but two complete upper and one lower second molars were obtained. One tusk, about 7 or 8 feet long, was also found. The lower ends of both femora were destroyed in the original trench, but of the other limb-bones nearly complete specimens from one or both sides have been obtained, as well as a sufficiently large series of bones of the feet to allow of their reconstruction. Many vertebræ were also collected.

The animal, which was adult, must have been of very large size, having stood about 15 feet at the highest part of the back, or more than 3½ feet higher than the large African elephant mounted in the Entrance Hall of the Natural History Museum.

The molar teeth show conclusively that the species represented is *Elephas antiquus*, and from the thickness of the enamel and some other characters, it may be inferred that the animal was probably of a type as early as, or earlier than, that found at Grays. It is the first British example of this species in which the skeleton has been found directly associated with the teeth.

Lantern-slides and remains of *Elephas* were exhibited.

Mr. G. C. Crick, F.G.S., exhibited two Nautili from the Upper Cretaceous rocks of Zululand. Each showed approximation of the last three septa, indicative of the comparatively sudden arrest of growth of the animal and of the accompanying forward movement of the animal in its shell, a character usually attributed to senility. One specimen showed also irregularities of depth in the other chambers of the camerated part of the shell.

CORRESPONDENCE.

EARLY MAN AND HIS IMPLEMENTS.

Sir,—With reference to Mr. Reid Moir's letter in the October Number of the Geological Magazine criticizing M. Boule's recent paper in *Anthropologie*, the Abbé Breuil requests me to ask you, on his behalf, the favour of publication of the following remarks, and copy of his letter to me of February 27, 1913.

"PARIS, *Oct. 29, 1915.*

"I ask this publication relying on my right of reply, since I deem it beneath my dignity and scientific repute to reply directly to the poor and arbitrary attack of Mr. Reid Moir against my scientific independence and experience.—H. BREUIL."

F. N. HAWARD.

49 QUEEN VICTORIA STREET, E.C.
November 2, 1915.

[COPY.]

"110 RUE DEMOURS, PARIS.
February 27, 1913.

"DEAR MR. HAWARD,—I am entirely of your opinion concerning the so-called Pre-Palæoliths (or 'Eoliths') of Mr. Reid Moir and Sir Ray Lankester. Your article[1] is very strong against them, but, as with all their 'Eolithic-loving' confrères, it is difficult to discuss with these gentlemen. They affirm their opinions with too much enthusiastic conviction, which prevents them from appreciating the rights of others to doubt.

"The 'Eoliths' of the Pre-Crag bed of these gentlemen are really much older than the deposit which contains them; probably they came from the remains of Miocene or very old Pliocene, or of beds of the sort you have described. If they had been chipped by intelligent beings, it would not have been during the Pliocene period, but at a period too early for the probable geological antiquity of mankind, because it would be necessary equally to admit not only Le Puy Courny (Miocene) but Boncelles, which is at least Oligocene. Now at Boncelles M. Rutot has discovered at the side of his so-called 'human station' a spot yielding similar flints to those of Belle Assise, but much finer, resulting evidently, even in his opinion, from movement of the soil.

"I have brought to these gentlemen the best flints from Belle Assise. Mr. Reid Moir would not say that these were not made by Man. Sir Ray Lankester was more prudent: he said 'that they were not due to pressure'. I replied that in any case the fracture and the 'retouching' were produced after they were embedded in the Eocene sand. 'Sand like water produces nothing by pressure,' so far as static pressure is concerned, but movement of the soil, as you say so well, produces formidable compression.

"There are some who believe that two or three laboratory experiments are equivalent to the mechanism so complicated and so varied as is that of Nature. There are experiments that one cannot reproduce in the laboratory, and others which are not worth the trouble, or which would cost too much to demonstrate an evident thing. And yet these gentlemen say that it has been done by machinery, and that consequently this proves nothing (as in the case of Mantes).

"When one examines the geological formation of the 'Sub-Crag beds', where one finds the so-called 'Rostro-Carinates' and accompanying flints, it is striking that in all the pits where they can be seen one always finds them infallibly and abundantly. This fact is evidence that one is in the presence of a *geological and not an archæological phenomenon.* Also, there are many other flints in these beds besides those which have been presented as 'humanly worked'; some show no fracture, others one or two or a few fractures without signification, others are doubtful, although more elaborate in appearance, even in the opinion of the enthusiasts. Others carry written on their facets and edges the history of their long misadventures; the 'patina' of the facets proves the repeated action by the mechanical forces which is convincing to unbiassed minds well disposed to discuss dispassionately.

"Probably there was a relation of 'cause and effect' between the production of scratches and the chipping of the edge of the opposite side. One would say

[1] "F. N. Haward, 'The Chipping of Flint by Natural Agencies': Proc. Prehistoric Soc. E. Anglia (read December 4, 1911)."

the flints were fixed in such a manner that a moving mass of ice or earth slipped over, scratching the upper face and 'retouching' the opposite.

"One can often see that the predominating direction of the scratches is almost normal at the chipped edges. Sometimes it is evident that the hard substance which has incised a deep scratch has also dug, in some place where its action has been prolonged, a little 'cupola of contusion'. Later the line was continued as far as the more fragile edge, where the flint breaks, giving a bunch of chips on the other side, thus *simulating a concave scraper.*

"These explanations account for most of the so-called 'worked flints' of Pre-Crag beds and are very like those which you proposed. But it is astonishing that to obtain a good type of 'rostro-carinate' or similar 'implements' so many renewals of chipping of very different ages were necessary.

"So it seems some of the chipped facets can be Eocene, and the continuation of the same working could be Miocene or Pliocene. In any case, the difference of the age between the successive chippings is so great that it excludes the probability of the work of man. Otherwise very different actions seem to have collaborated. Probably in the first bedding of these flints there was the same compression as at Boncelles and Bellè Assise; afterwards they were transported by diverse forces (more or less violent) which have left sometimes traces extremely energetic. Others, specially, more or less deeply graven lines, generally limited to one side, are to be considered. Often the other side is similarly favoured by abundant 'retouching'.

"I believe it is necessary to exercise very great caution and possess much familiarity with both 'natural' and 'artificial' chipping of flint to enable one to distinguish the difference. In many cases the natural fracture gives the same appearance as the rough working and chipping of Man. So it is sometimes impossible to distinguish between the work of Nature or Man, and the proof will come from another source than the morphology, which is too deceitful, because the natural inclination of the human imagination is towards the 'morphomanic'.

"*As to the Ipswich skeleton*, I think that it is senseless to present it as 'Pre-Glacial'. The superdeposited soil is evidently due to the alteration and transport of Boulder-clay down the slope. It is not Boulder-clay, it is a dateless deposit (limon). The body had the position of a buried person, fairly old, perhaps Neolithic. A grave dug in non-stratified soil would not have left any trace after a considerable time. The decalcified soil of the clay and of the grave ('Middle Glacial') would not have permitted the preservation of a body so old at such a shallow depth.

"Finally, the position of the body is absurd. If the body had been abandoned on the seashore it would have been dismembered, and the bones would have been separated, rolled, destroyed. If the body is later than this marine plateau (and it is, since it is partly in the overlying bed), then it dates from this later bed; but if so, if it was a 'moraine de fond', the man could not have been precipitated into it, neither dead nor alive, and a body on the shore of the Middle Glacial sands would have suffered terrible injuries from the glacier. The bones would have been crushed, disjointed, and dissolved by the waters of the glacier.

"All this is incomprehensible on the hypothesis of Mr. Moir, and, on the contrary, is amply explained by yours and mine—burial in date probably late prehistoric, in a modern soil derived by means of the alteration and the reshuffling of the chalky Boulder-clay.

"H. Breuil."

THE ALKALINE ROCKS OF SOUTH-WEST AFRICA.

Sir,—Since reading Mr. Holmes' paper on the alkaline rocks of Angola (Geol. Mag., July and August, 1915) I have thought that a brief note on the somewhat similar rocks occurring near Pomona and in Namaqualand may be of immediate interest. I received a collection of these rocks from Dr. A. W. Rogers in 1914, and I intend to visit the localities myself to make a fuller study than is possible in the laboratory. In the meantime the following notes may be of interest.

The nephelite-syenite of the Granitberg was described very briefly by Wagner. It is a foyaite with a very variable amount of nephelite, which may locally make up two-thirds of the rock. The chief dark mineral is a green ægirite-augite. This rock is cut by two dykes of a singularly interesting microfoyaite which contains, in addition to microperthite, nephelite, and pyroxene, smaller amounts of biotite, perovskite, and zircon. The perovskite forms perfect octahedrons up to half a millimetre in diameter. Zircon occurs in skeletons and irregular groups and plates, and often encloses grains and laths of felspar. The dark minerals amount to just under 10 per cent of the rock.

From the neighbourhood of Pomona there are several monchiquites and camptonites, some fresh and others too much decomposed for certain identification. In one of the camptonites, crystals of barkevikite are enclosed by titanaugite with a reaction rim of magnetite separating the two. In all these lamprophyres there are pseudomorphs of a mineral like iddingsite, apparently replacing olivine. I have also a beautiful ægirite-solvsbergite with marked flow-structure, and some typical bostonites and lindöites. Dr. Rogers has also found numerous bostonite dykes in Van Rhyn's Dorp and Namaqualand.

I hope to publish a full account of these interesting rocks in the course of time.

S. J. Shand.

Geology Department, Victoria College,
Stellenbosch, S.A.
October 1, 1915.

BURSTING OF A LAKE BARRIER IN ARGENTINA.

Sir,—It is not often that one finds anything of geological interest in the report of a railway company, but the following details from the Report of the Directors of the Buenos Ayres Great Southern Railway Company for the year ended June 30, 1915, are interesting.

"The most sensational, although by no means the most costly, of the long series of mishaps due to this cause [the weather], was the cataclysm in the Rio Colorado Valley in the early days of January, when some thirty-six miles of the Railway were submerged under deep water, and traffic on the Neuquen line beyond Gavietas was entirely cut off for almost a month. This stupendous, and at first inexplicable visitation, was discovered to be the outcome of the sudden release, 350 miles away from the line as the crow flies, of an immense body of water called Lake Carrilauquen, which had been formed by a landslide at a comparatively recent geological epoch. Owing to stress of weather this natural dam suddenly gave way and thus launched 2,800,000,000 tons of water into the valley of the Rio Colorado."

The lake is nearly 6,000 feet above the sea-level. It was some 15 miles long, $1\frac{1}{4}$ miles wide, and over 300 feet deep at the lower end.

Bernard Hobson.

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