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NEW SERIES.

DECADE VI. VOL. I.

JANUARY—DECEMBER, 1914.

THE

GEOLOGICAL MAGAZINE

OR

Monthly Journal of Geology.

WITH WHICH IS INCORPORATED

THE GEOLOGIST.

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EDITED BY

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

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

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LIST OF PLATES.

LIST OF ILLUSTRATIONS IN THE TEXT.

FOREWORD.

TO OUR SUBSCRIBERS AND SUPPORTERS.

IN the June Number of the present volume, we issued our 600th monthly part and recorded with pleasure the successful completion of the 50th year of the existence of the GEOLOGICAL MAGAZINE, a record of Editorship of which we felt justly proud.

During the subsequent months of the year the Magazine has continued its peaceful course, but our country has been passing through a period of trial, anxiety, and sorrow entailed by the outbreak of the greatest European War ever recorded.

Although Naval and Military news and warlike undertakings occupy a large share of our thoughts and attention, it must be a great pleasure to turn from these national anxieties to the tranquil pursuits of geology and palæozoology and find in the pages of the GEOLOGICAL MAGAZINE a relief from the too frequent records of "battle, murder, and sudden death" with which the daily Press has unfortunately so often to indulge its readers.

May I venture to suggest that by turning your thoughts to our beloved science you will find a solace and relief from "war's alarms", and that the Editor may still rely upon your kind support for the New Year.

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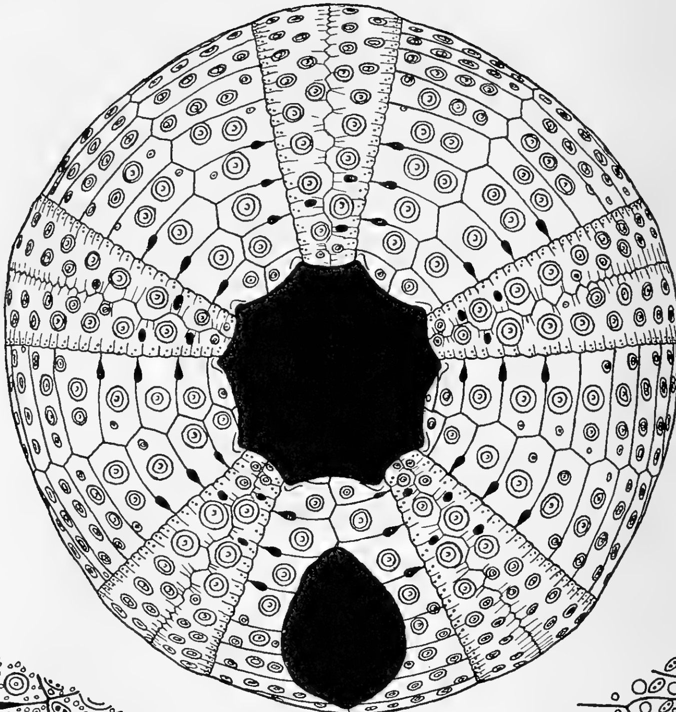

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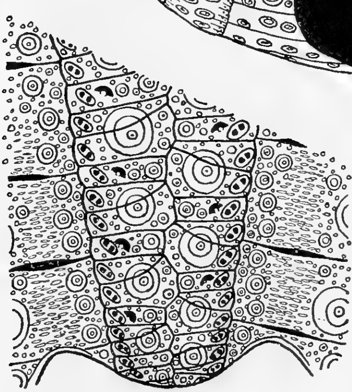

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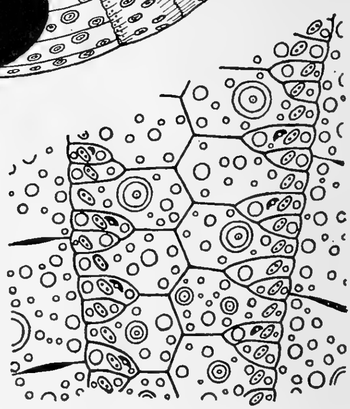

3

H. L. H. del.

Enlarged drawing showing the positions and relations of the pits of the adoral surface in some Holectypoida.

Fig. 1, × 6; Fig. 2, × 6; Fig. 3, × 11.

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NEW SERIES. DECADE VI. VOL. I.

No. I.—JANUARY, 1914.

ORIGINAL ARTICLES.

I.—Some Problematical Structures in the Holectypoida.

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

(PLATE I.)

DURING a detailed examination of the tests, and in particular of the ambulacra, of the common British species of the Echinoidea Holectypoida, I have found two series of structures the correlation of which, with those known in recent forms, seems difficult. Since I am engaged in the preparation of a description of the British Pygasteridæ, I have thought it advisable to publish now an account of these peculiar features, in the hope that others may be able to throw light on points that seem to me obscure.

The structures to which attention is drawn are both of the nature of sculptured pits on the coronal plates, and seem to be restricted to the adoral surface. One series of pits is ambulacral in position, the other interambulacral. The former series is not associated with any neighbouring peculiarities; the latter is so situated that it seems to be in some way connected with the external branchiæ. The former set of pits is very minute, and is, I believe, recorded for the first time; the latter is often quite conspicuous, and has been figured frequently, usually without comment, by previous observers. I have found no traces of either series of pits in *Conulus*, but both are present in *Pygaster* '*semisulcatus*', *P.* '*umbrella*', *Holectypus depressus*, *H. hemisphæricus*, *Coenholectypus serialis*, and *Discoidea cylindrica*. The succeeding remarks are based solely on an examination of those species.

I. The Ambulacral Pits.

These I noticed first in *P.* '*semisulcatus*', but found subsequently to be more conspicuous in *H. depressus*, and most strongly marked in *C. serialis*.

The ambulacral plates of the Holectypoida are always potentially triads, on one member of which stands a prominent tubercle belonging to the main (ambulacral) series. When compression of the plates occurs, the one with the large tubercle generally remains of considerable size, the plate immediately above it becomes a demi-plate, while that below it, while often retaining its primary character, loses in height and may become cuneiform (see Pl. I, Fig. 2). In *Discoidea* and *Conulus* this plate becomes completely severed from the perradial suture (see Pl. I, Fig. 3). In *Pygaster* the pore-pair of this lowest plate of the triad is generally further removed from the adradial suture than is the case with the other two. Whenever the pits under consideration can be seen, they are found to occur on this plate, and therefore are situated adorally to the areolæ of the large tubercles.

In *P. 'semisulcatus'* (Pl. I, Fig. 2), counting from the peristome, two triads in each column of the ambulacra are normal, but the succeeding five show the structures in question. On the lowest plate of each of these five triads, almost impinging upon the peripodium, is a minute, crescent-shaped depression. The horns of the crescent point obliquely adorally and adradially, and between them, where the depression is becoming shallow, there is a minute granule. As far as can be seen, this granule is similar in shape and size to those of the ordinary parts of the plates. But whereas all the ordinary granules may be said to have an axis at right angles to the test surface, these slightly sunken ones have an axis sloping away from the peristome, directed more or less into the depression on whose brink they stand. On the side of each depression, away from the peripodium, there is constantly a small tubercle, the persistent occurrence of which is noteworthy in view of the apparent irregularity in distribution of such tubercles in other regions. It seems to indicate that the structures associated with the depression were sheltered beneath a specially placed secondary radiole.

Owing to the superficial nature of the depressions very well-preserved specimens are necessary for their perception, but I have been able to satisfy myself that they are constant in number and position in five examples of *P. 'semisulcatus'* in my collection. It seems likely that their characters are similar in *P. 'umbrella'*, but in the material at my disposal they are not very clearly shown.

Pits of a like distribution and nature occur in *Holectypus depressus* and *H. hemisphæricus*, but their numbers seem to be variable, even on the ambulacra of a single specimen. This irregularity may, however, be due to imperfect preservation.

In *Coenholectypus serialis* the corresponding pits are much more pronounced (Pl. I, Fig. 1). The only specimen in my collection (now transferred to the geological department, University College, Reading), of which the peristomial region is exposed, is slightly weathered, and all but the larger surface features have been destroyed. In spite of this the pits are clearly visible, particularly after the specimen has been stained with dilute Indian ink. As in *Pygaster*, two more or less complete triads (counting from the peristome margin) seem to be devoid of pits. These when they occur are fewer in number than in the Oolitic genus, there being only three in each area, except in amb. V, where there are four, two in each column. They show no signs of being crescentic in shape, but seem roughly elliptical in plan, and uniformly depressed throughout. No granules can be seen in them, but since all such structures have been destroyed on the rest of the test, it is fair to assume that they were present. The distribution of the pits is interesting. There are two in columns Ia, IIa, IIIb, IVa, Va & b, and one only in columns Ib, IIb, IIIa, IVb. It will be noticed that, except in area V, the occurrence of the pits is in strict accord with the order of plate-development as determined by Lovén (*Études*, p. 13).

In *Discoidea cylindrica* (Pl. I, Fig. 3) the pits are far less deep, even than in *Pygaster*. Indeed, it was not until I was drawing an ambulacrum of this species under a high power of magnification with specially arranged lighting, and examining each granule separately, that I discovered them. Unfortunately none of the material I have yet seen is sufficiently weathered around the invaginated peristome to give a clear view of the adorally situated plates. But, although the lower plates of the triads are demiplates, and of very restricted area, the four next outside the border of the invagination show the pits. They are crescentic, and similar, save in point of size, to those of *Pygaster*.

Whatever may be the significance of these pits, and however much the extent of their distribution may be enlarged by further research, I feel confident that they have essentially the positions indicated above, and that nothing like them occurs on the other plates of the triads. The nearest approach to them seems to be found in the sunken tubercles met with on the adapical surface of the Cornbrash form of *Holectypus depressus*, but those are on the interambulacral plates between the central tubercles of the main series (see Hawkins, Geol. Mag., 1911, p. 444, Fig. 1, H). The restriction of the pits in question to the ambulacra at once suggests a comparison with the pockets for sphæridia, and this is the only suggestion as to their meaning that I can offer. Their arrangement (in reduced numbers) in *C. serialis* is strongly reminiscent of the distribution of the sphæridia in *Echinonëus* (Westergren, 1911), and the presence of four of them in one area, would seem to compare with the four sphæridia figured by Lovén (*Études*) for that genus. But very great difficulties are encountered if the comparison between the pits of the Holectypoida and sphæridia be carried further. In *Pygaster* and *Discoidea* they extend to a considerable distance from the peristome, and seem not to occur in its immediate neighbourhood. It is true that in many advanced Spatangoids sphæridia, or at least their pits, occur at an even greater proportionate distance from the peristome, but they occur on every plate, there being no intervening plates as in the Holectypoids.

A comparison is possible between these pits and the curious sunken granules (bearing 'glassy tubercles') in *Echinonëus*, and the probably similar pits that occur thickly scattered over the test of *Conulus*. However, the restricted distribution of these ambulacral pits seems to point to some more special and localized function than could be ascribed to glassy tubercles.

As the matter stands at present, these depressions would seem to be either the pits for sphæridia (in which case their distribution is unique) or some special structure not yet recognized in recent forms.

II. The Suprabranchial Depressions.

In all the Holectypoida, with the partial exception of *Conulus*, the branchial slits make conspicuous indentations on the margin of the peristome, the deepest part of the incision being situated just in the interambulacrum. Passing from the peristome, near the adradial suture, but separated from it by a row of fairly prominent tubercles and granules, is a slightly depressed groove that extends over about four of the interambulacral plates. This groove is generally smoother than the surrounding parts of the test, and the granules occurring in it are often unlike those outside. In *Pygaster* they are usually abundant and minute, most of them being transversely elongated. In *Holectypus*, and particularly in *H. depressus*, they are relatively few in number, of fairly large size, and guttate in plan, tending to radiate from the areolæ of the main tubercles. In *Discoidea* there is hardly any difference between the granulation of the groove and that of the surrounding regions.

At the places where the 'suprabranchial groove' crosses the transverse sutures there are developed elongate depressions. Three such hollows commonly occur in each groove, those nearest to the peristome being usually the most deeply excavated. They are completely devoid of granules, and in the case of *Discoidea* are each surrounded by a smooth, ovoid area, flush with the test surface. The pits are more deeply cut in *Coenholectypus serialis* than in any other form I have examined (Pl. I, Fig. 1). Here they are more or less pyriform in outline, the pointed end being directed towards the adradial suture.

The fact that the shallow grooves into which these depressions are trenched seem to originate at the branchial slits, makes it probable that they must have some function connected with the external branchiæ. However, the distance to which the grooves and pits extend from the peristome is far greater than one would expect the branchiæ themselves to traverse. In most regular Ectobranchiates the 'gills' are small bunches of vascular tubes that hardly project beyond the peristomial membrane, and they are protected from the radioles and pedicellariæ of the adjoining plates by a smooth lip-like area. A similar 'lip' is present in the Holectypoida, so that it seems probable that the nature of the 'gills' was also similar.

The curious guttate and elongate granules of the suprabranchial groove may perhaps have supported pedicellariæ of a special kind that would act as 'gill-rakers'; but this supposition of course involves the capability of such organs for reaching the branchiæ. But I can suggest no function or meaning for the depressions along the sutures in this region. Their invariable presence, and frequently considerable depth, seem to indicate that they are structures of some physiological importance. They resemble the sutural excavations common among the Temnopleuridæ (these occur in at least one Holectypoid genus, *Coptodiscus*). Whatever may be the value of the pits in those forms, the restriction of these depressions to the suprabranchial groove must indicate a more localized function. They are certainly quite different from the ambulacral pits above described. The latter are *on* the plates, not between them, and contain a granule, whereas the suprabranchial pits are particularly smooth.

To sum up: the Holectypoida (except *Conulus*) possess two series of excavations on the test near the peristome. One series, ambulacral in position and regularly situated with regard to the triads, may possibly have lodged sphæridia, although there are many difficulties met with in such a view. The other series is interambulacral, placed on the transverse sutures in the suprabranchial groove. For this no function can be suggested, but it is hoped that future work, particularly on recent material, may throw some light on the problems here stated.

EXPLANATION OF PLATE I.

The figures have been drawn with the help of photographs, copied by means of an Edinger Projection apparatus. The ambulacral pits and suprabranchial depressions are represented in black for the sake of clearness, but must not be confused with the actual perforations of the test. The figures are not diagrammatic in any other way.

FIG. 1. Adoral surface of a small specimen of *Coenholectypus serialis* from the Senonian of Algiers (Univ. Coll., Reading, Geol. Museum, No. F. 284). × *c.* 6. The ambulacral pits are seen to occur in series conformable to Lovén's law, except in area V. The interambulacral depressions are pyriform, pointing adradially.

FIG. 2. Part of the adoral region of amb. III of *Pygaster* '*semisulcatus*', with the adjoining parts of the interambulacra. × *c.* 6. The ambulacral pits are crescent-shaped depressions (each enclosing a small granule) seen near the peripodium on the lowest member of each triad (except the two proximal ones). The interambulacral depressions are conspicuous, and the granules of the suprabranchial groove are seen to be transversely elongate and arranged in a linear fashion.

FIG. 3. Part of the adoral region of amb. I of *Discoidea cylindrica*, with the adjoining parts of the interambulacra. × 11. The lower part of the figure coincides with the beginning of the peristomial invagination. The ambulacral pits are similar to those of *Pygaster*, but much smaller in proportion. The suprabranchial depressions are also smaller, and are surrounded by an area devoid of granules.

II.—ON *HERPETOPORA*, A NEW GENUS CONTAINING THREE NEW SPECIES OF CRETACEOUS CHEILOSTOME POLYZOA.

By W. D. LANG, M.A., F.G.S.

(PLATE II.)

IN a report[1] on a visit of the Geologists' Association to the exhibits of Polyzoa and Corals in the Geological Department of the British Museum in February, 1913, the author had occasion to mention two related and unnamed species of uniserial Chalk Polyzoa that hitherto had appeared in records as *Hippothoa dispersa* (von Hagenow), neither of which was this species, nor did either belong to the genus *Hippothoa*, Lamouroux.[2] Since one of these two forms is very common in the English Chalk and the other not rare, it is time for a description of them to be published, that collectors may have distinctive names for them. In addition, a third form that has occurred in England is described, and the rest of the species included in the genus are mentioned, so that an idea of the genus as a whole may be formed.

HERPETOPORA,[3] n.gen.

Diagnosis.—Incrusting, uniserial, Cheilostome Polyzoa, in which each individual normally has either a distal or one distal and two

[1] Proc. Geol. Assoc., vol. xxiv, pt. iii, pp. 171–2, 1913.

[2] Lamouroux, *Exposition Méthodique des genres de l'Ordre des Polypiers*, 1821, p. 82. The genotype is the recent *Hippothoa divaricata*.

[3] *το ἑρπετόν*, 'a creeping thing.'

lateral buds, so that the normal mode of branching is 'bilateral'; no avicularia, but heteromorphic individuals may occur; normal zoœcia consisting of a distal 'capitular' and a proximal 'caudal' portion, though in young zoarial stages, as evidenced by recapitulation at the branches, the caudal portion is very short or absent; front wall divided by a plain, more or less oval rim, the 'termen', into an inner and outer portion—the intra-terminal and extra-terminal front walls; the former consists of a narrow, calcareous terminal bevel, hardly wider proximally than distally, and (presumably) of a chitinous portion not preserved in the fossil state; extra-terminal front wall entirely calcareous, plain, with no median proximal ridge or groove. Sealed and renewed zoœcia very common.

Note.—Hippothoa, in which the two following species have hitherto been placed, has a completely calcareous front wall.

Genotype.—Herpetopora anglica, n.sp.

Herpetopora anglica, n.sp. Pl. II, Figs. 1–3.

Diagnosis.—Herpetopora with zoœcia that taper somewhat distally as well as proximally; with regularly elliptical termens and (in ephebastic zoœcia) with very long, straight caudal portions. Heteromorphic individuals of unknown function, but not avicularia, occasionally occur.

Note.—The distal tapering distinguishes *H. anglica* from pear-shaped forms such as *H. clavigera*, n.sp., *Hippothoa cruciata*, Reuss,[1] and *H. gracilis*, d'Orbigny,[2] and the regularly elliptical termens and straight caudal portions from *H. labiata*, Novak,[3] and *H. desiderata*, Novak.[4] *Cellepora dispersa*, von Hagenow,[5] to which this form is usually referred, is not even a *Herpetopora*. It has a beaded termen and definite avicularia on the caudal portions of the zoœcia; it is found in the *mucronata* zone at Rügen.

Type-specimen.—British Museum specimen D. 11359; Senonian, top of zone of *Micraster cortestudinarium* or base of zone of *M. coranguinum*; Chatham, Kent; W. Gamble Collection.

Distribution.—Turonian, zone of *Terebratulina*, to Senonian, zone of *Marsupites*. Common in zone of *Micraster cortestudinarium* and in lower part of zone of *M. coranguinum*.

Herpetopora clavigera, n.sp. Pl. II, Figs. 4–5.

Diagnosis.—Herpetopora with zoœcia hardly tapering distally and consequently more or less pear-shaped, having their outlines bounded by steeply curved sides, more so than in *Hippothoa cruciata*, Reuss,[6]

[1] Reuss, Denk. d. Kaiserl. Akad. d. Wissensch. Wien, Bd. vii, p. 134, pl. xxviii, fig. 1, 1854.

[2] D'Orbigny, *Paléontologie Française; Terrains Crétacés*, vol. v, p. 386, pl. 711, figs. 9–11, 1852–3. It is very doubtful whether this form should be placed here.

[3] Novak, Denk. d. Kaiserl. Akad. d. Wissensch. Wien, Bd. xxxvii, pt. ii, p. 86, pl. iii, figs. 1–5, 1877.

[4] Novak, op. cit., p. 86, pl. ii, figs. 1, 2, 1877.

[5] Von Hagenow, 1839, *Neues Jahrbuch f. Min.*, etc., p. 280. For figure see Marsson, *Pal. Abhandl.*, Bd. iv, Hft. i, p. 91, pl. ix, fig. 9, 1887.

[6] Reuss, loc. cit.

which has them gently curved, and *H. gracilis*, d'Orbigny,[1] in which the sides are nearly straight.

Type-specimen.—British Museum specimen, D. 20607; Senonian [zone of *Belemnitella mucronata*]; Norwich; T. G. Bayfield Collection.

Distribution.—Senonian, above the zone of *Marsupites*.

HERPETOPORA DANICA, n.sp. Pl. II, Figs. 6–7.

A third species of *Herpetopora* is represented by two specimens in the British Museum from the Danian of Faxe, Denmark; and another specimen from the *mucronata* zone of Norwich is in the collection of Dr. Rowe, who kindly lent it to me for examination and description. Other species which probably should be placed in this genus are *Hippothoa labiata*, Novak, from the Cenomanian of Bohemia; *H. desiderata*, Novak, from the lowest Senonian of Bohemia; *H. cruciata*, Reuss, from the Turonian of the Austrian Tyrol; and *H. gracilis*, d'Orbigny, from the Senonian of Tours, Indre-et-Loire.[2]

Diagnosis.—*Herpetopora* with large zoœcia tapering somewhat distally, with oval rather than elliptical[3] termens, and with very short caudal portions.

Remarks.—The shorter termens and caudal portions as well as the large size of the zoœcia distinguish *H. danica* from *H. anglica*, which it otherwise resembles.

Type-specimen.—British Museum specimen, D. 19429; Danian; Faxe, Denmark; J. W. Davis Collection.

Distribution.—Senonian, zone of *Belemnitella mucronata*; Thorpe St. Andrew, Norwich (A. W. Rowe Collection). Danian; Faxe, Seeland, Denmark (British Museum specimens, D. 19429, D. 9113, J. W. Davis and Miss Caroline Birley Collections).

KEY TO THE GENUS *HERPETOPORA*.

A. Zoœcia tapering at both ends.
   1. Termen regularly elliptical or oval; zoœcia with caudal portions very straight.
      a. Termen oval rather than elliptical; caudal portions of zoœcia very short or absent . . . . . . *H. danica*
      b. Termen elliptical rather than oval; caudal portions of zoœcia very long (except as a neanastic character) . *H. anglica*
   2. Termen irregularly elliptical; capitular and caudal portions of zoœcia slightly wavy . . . . *H. labiata* (Novak)
   3. Termen irregularly elliptical; zoœcia, especially the caudal portions, wavy; zoœcia sometimes tend towards a pear-shape as in B . . . . *H. desiderata* (Novak)

B. Zoœcia tapering proximally and ending fairly abruptly distally.
   1. Proximal capitular parts of zoœcium bounded by nearly straight lines . . . . *H. gracilis* (d'Orbigny)
   2. Proximal capitular parts of zoœcia bounded by gently curved lines . . . . *H. cruciata* (Reuss)
   3. Proximal capitular parts of zoœcia bounded by sharply curved lines . . . . *H. clavigera*

[1] D'Orbigny, loc. cit.

[2] For references to the original descriptions of these species see footnote under *Herpetopora anglica* on p. 6.

[3] Oval and elliptical used in the botanical sense, as defined, for instance, in Asa Gray, 1879, *Structural Botany*, p. 95.

FIG. EXPLANATION OF PLATE II.

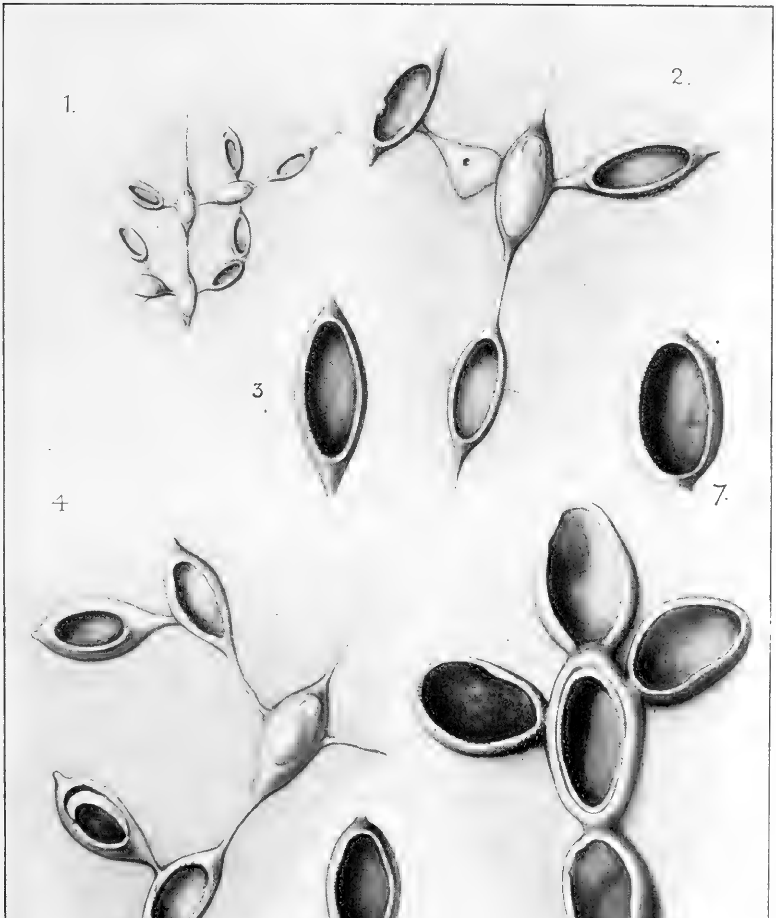
1. *Herpetopora anglica.* A piece of zoarium showing the method of branching typical of the genus *Herpetopora.* Of the ten zoœcia shown four are sealed and three are renewed zoœcia. × about 11 diameters. The type-specimen; British Museum specimen No. D. 11359. Senonian, top of *Micraster cortestudinarium* zone or base of *M. coranguinum* zone. Chatham, Kent. W. Gamble Collection.
2. *H. anglica.* Pieces of two branches of a zoarium, more highly magnified than Fig. 1. One zoœcium is sealed, three are normal, and the remaining zoœcium is a heteromorphic individual of unknown function. × about 27 diameters. Part of the same specimen as Fig. 1.
3. *H. anglica.* A single normal zoœcium still more highly magnified than Fig. 2. × about 33 diameters. The zoœcium is the same as that at the lower right-hand corner of Fig. 1.
4. *H. clavigera.* A piece of zoarium magnified approximately to the same extent as Fig. 2. One sealed and three normal zoœcia are shown; two of the latter are much broken. × about 25 diameters. The type-specimen; British Museum specimen No. D. 20607. Senonian, zone of *Belemnitella mucronata.* Norwich. T. G. Bayfield Collection.
5. *H. clavigera.* A single normal zoœcium from another part of the specimen from which Fig. 4 is drawn, magnified to the same extent as Fig. 3. × about 30 diameters.
6. *H. danica.* A piece of zoarium magnified approximately to the same extent as Figs. 2 and 4, bearing four normal and one renewed zoœcium. × about 24 diameters. The type-specimen; British Museum specimen No. D. 19429. Danian. Faxe, Seeland, Denmark. J. W. Davis Collection.
7. *H. danica.* A single normal zoœcium from the zoarium of which Fig. 6 is a part, magnified approximately to the same extent as Fig. 6. × about 24 diameters.

III.—The Value of a Knowledge of the Rock-soil Distribution of Plants in tracing Geological Boundaries.

By A. R. Horwood.

THOUGH ecology has been studied for a long period on the Continent it is only within the last ten years that it has become an important branch of botany in this country. Now, however, it is one of the most ardently pursued sciences, and has made great progress. That branch of it which deals with soil factors, or the distribution of plants upon different soils and a knowledge of the nativity of plants upon particular soils, has received considerable attention, and sufficient data have been accumulated to state the principle that each rock-soil supports a characteristic flora: so that the type of soil may be regarded as an index to the type of vegetation of any district where that rock-soil is dominant; and in the same way it is possible to state by a recognition of the type of vegetation the character of the rock-soil.

Whilst emphasizing these main features it should not be forgotten that exceptions occur, and that composite rock-soils are liable to obscure the clear evidence afforded by self soils or those that are pure. But they do not by any means invalidate the importance of these main principles. The influence of man, largely through agriculture, traffic, industry, building, etc., upsets in some cases the normal features noticeable in an undisturbed state of nature. But this is inevitable, and must be taken into account in all biological work.



G. M. Woodward del.

The genus *Herpetopora*.

In using the word rock-soil in a special sense, to denote the soil afforded by any particular rock or geological formation, ancient or recent, by whatever agency formed or accumulated, it should be pointed out that though there are, broadly speaking, quite fifty, if not more, such types, yet the distinctive types of soil which exhibit marked differences in composition, chemical and physical characteristics, are briefly six in number: clay loamy sand, siliceous soils, limestone or chalk, peat (raw or acid), humus (raw or acid), and saline soil. Particularly is the presence of lime in a rock-soil a predominating factor in plant dispersal, so that we speak of calcicole and calcifuge species. The same applies to peat, humus, salt, and in a less degree to clay, sand, and silica, since these last are liable to be frequently mixed in varying proportions, and the existence of marls affords a passage from arenaceous to calcareous types.

If this is so it is obvious that the principles stated (akin to those of William Smith) must have an important bearing upon geology, especially in the possibility of determining thereby, in the field, where palæontological data are wanting, the existence of definite zones and subzones. The very vegetation which to the pure geologist is the cause of obscuring the sequence, may in this way by ecological methods be a means of determining their position, a paradox which, however, is quite intelligible if one bears in mind the principles of Smith that strata are characterized by their organic remains, more particularly so as in the case of plant-bearing formations, such as the Coal-measures, it is possible to show that there was in the past, as in the present, an ecological association of plants, that is to say, that dry soil plants are found as they grew in certain associations, whilst wet soil or aquatic types are found and grew in different positions, or at different horizons, or can be found to have a different geographical distribution. In particular such formations as the Trias (Keuper, Rhætics), the Lias, etc., have intermittent bands of limestone, skerries, etc., which are not always to be seen in the field, in section or otherwise, and in such cases there is often considerable difficulty, especially in faulted regions or where drift obscures the solid rocks, in tracing such beds across country. In the same way the existence of irregular beds of sand in glacial deposits is often obscured by vegetation or other causes, and their existence, and their extent and area, is often a pure matter of conjecture, frequently only to be ascertained by aid of well-borings or other operations of the kind. As the delineation of clay and sand, and the mapping of such details, are of great importance, especially to the builder, agriculturist, and horticulturist, and economic geology is to-day a great factor in survey work, any accessory aids that can be rendered by the ecologist are worthy of the consideration of geologists. And these are only a few of the ways in which a study of rock-soil distribution of plants may serve the geologist in good stead. Moreover, ecology has already advanced so far that surveys upon a systematic and well-organized plan have been made, and exact vegetation maps published, so that it is hoped and expected that this science, which is of such importance from the economic as well as the stratigraphic standpoint, will have shortly to be established upon a national basis, and ecological surveys carried out by the State. This opinion has, in fact, already been stated by ecologists. This necessity of course arises primarily from the purely ecological value of the work, and since ecology and geology are, as I have shown, interdependent, there is thus additional reason for urging that the former be recognized, as fully as the latter, as of national importance, and therefore worthy of public support of a financial kind.

It is therefore suggested that till this is accomplished, if it meets with approval in this quarter, geological survey work should be definitely carried out in conjunction with ecological surveys. Soil surveys have been made in conjunction with experimental stations at the instance of the Geological Survey, and the further step I advocate in this direction would be of a similar kind and for a similar purpose, though on a wider basis. At any rate it might be possible that those at work in each district, upon ecological surveys, should be asked to co-operate, where required, with geological surveyors, especially in those areas where this co-operation would be of great assistance in tracing boundaries of local beds.

It is further suggested, if this be possible, that a definite effort should be made to accomplish the appointment of Government ecological surveys by those already officially in charge of geological work, in view of the assistance each science can render the other. Whilst emphasis has been laid here on the value of ecology to the geologist equal value is rendered of course by the geologist to ecology, and speaking as a geologist I might even say more. It must not be forgotten that, though little of this figures in literature, there are men who have for long noticed the connexion between plant dispersal and rock conformations in their systematic survey of the geological structure of the British Isles, if I mention only Sir Archibald Geikie and Mr. H. B. Woodward. A few examples of the data afforded by plants as to geological horizons may serve as an appendix to these remarks, but only a brief summary can be given and a selection of certain formations made.

Carboniferous Limestone.—Ash woods are the typical woodlands and would at once mark off a limestone district from a sandy district with sessile oaks as in Derbyshire. In such woods there is a predominance of one or two plants, such as *Mercurialis perennis*, *Adoxa moschatellina*, *Lamium galeobdolon*, etc. The open grass land of the massifs is characterized by such plants as *Reseda luteola*, *Arenaria verna*, *Geranium lucidum*, *Anthyllis vulneraria*, *Saxifraga tridactylites*, *Sedum acre*, *Helianthemum*, *Galium asperum*, *Origanum vulgare*, *Thymus serpyllum*, *Habenaria viridis*, *Allium vineale*, *Koeleria*, *Brachypodium pinnatum*. Where these plants occur, if no exposures were available, limestone could be mapped, and even if only one or two of the specially characteristic plants occurred this would be enough, so strong is their attachment to lime soils and their absence so well marked upon others.

In the case of the Keuper the uniform marl tracts are characterized more especially as being really more clayey and loamy than marly by oak woods with a particular ground flora. But the flora is rather an ordinary type, and is valuable in indicating rock formations where two different formations are exposed, as where Pre-Cambrian rocks with birch wood and *Aira flexuosa* adjoin red marl tracts. A feature of the sandstones is the occurrence of such arenophilous plants as *Erythræa*, and where the soil is more calcareous, of *Scabiosa columbaria* and *Gentiana amarella.*

In the case of the Rhætics the outcrop is so small and the individual beds so thin that plants are not confined to a zonal arrangement as in the overlying Lias.

In the Lower Lias there are limestone bands which may be indicated by such plants as *Poterium sanguisorba*, *Pimpinella saxifraga*, *Caucalis nodosa*, *Carum segetum*, *Carduus nutans*, *Cnicus acaulis*, etc.

Ironstone bands, or beds rich in iron, are indicated by the dominance of *Rumex acetosa.*

Clayey beds are revealed by the predominance of *Ranunculus ficaria*, *Lotus corniculatus*, *Conopodium denudatum*, *Scabiosa succisa*, *Tussilago*, *Petasites*, *Juncus conglomeratus*, *Rhinanthus*, *Ajuga.*

In the *Margaritatus* beds there are sandy horizons which are characterized by *Ulex*, *Stellaria graminea*, *Galium saxatile*, *Polygala vulgaris*, *Mercurialis perennis*, *Potentilla erecta.*

Some more clayey beds are indicated by *Pedicularis sylvatica*, *Lamium galeobdolon*, *Primula vulgaris*, *Saxifraga granulata*, *Galium uliginosum.*

Lime bands are indicated by *Reseda luteola*, *Silene noctiflora*, *Poterium sanguisorba*, etc. In the Rock-bed there are sandy beds upon which *Erophila vulgaris*, *Cerastium semi-decandrum*, *Geranium molle*, *Taraxacum erythrospermum*, *Myosotis versicolor*, *Veronica arvensis* are particularly abundant. On the purely clayey beds *Cerastium glomeratum*, *Malva moschata*, *Trifolium repens*, *Lathyrus pratensis*, *Anthriscus sylvestris*, *Stachys sylvatica*, *Tamus communis*, etc., are characteristic.

The Chalk plants *Papaver Rhœas*, *Viola hirta*, *Poterium sanguisorba*, *Echium vulgare*, *Linaria vulgaris* indicate bands of limestone, and so also do the following limestone plants: *Pimpinella magna*, *Centaurea scabiosa*, *Avena pratensis*, *Koeleria cristata.* It is generally characterized by *Myosotis collina*, *Cerastium arvense*, *Carduus nutans*, *Malva moschata*, *Chrysanthemum segetum*, *Scabiosa arvensis*, *Caucalis nodosa*, *Thymus serpyllum*, *Galeopsis Tetrahit*, *Silene noctiflora.*

The Inferior Oolite is characterized by beech and ash woods generally. Typical plants are *Helianthemum chamæcistus*, *Asperula cynanchica*, *Hippocrepis comosa*, *Campanula glomerata*, *Verbascum lychnitis*, *Carduus nutans*, *Carlina vulgaris*, *Calamintha acinos*, *Centaurea scabiosa*, *Filago germanica*, *Galium mollugo*, *Anemone pulsatilla*, *Geranium columbinum*, *Orchis pyramidalis*, *O. ustulata*, *Scabiosa columbaria*, *Galium erectum*, *Ononis repens*, *Origanum vulgare*, *Cephalanthera rubra*, *Senecio campestris*, *Herminium monorchis*, *Bromus erectus*, *Brachypodium pinnatum.*

The flora of the Northampton Sand is akin to that of the Marlstone, and *Scabiosa arvensis*, *Senecio Jacobæa*, *Centaurea scabiosa*, *Carduus nutans* distinguish it from that of the Upper Lias.

Boulder-clay consists in a large measure of clay with irregular patches of sand. These can be distinguished by the plants which respectively prefer clay or sand. On clayey beds the following are more prevalent: *Heracleum sphondylium*, *Lotus corniculatus*, *Potentilla anserina*, *Tussilago Farfara*, *Ranunculus bulbosus*, *R. repens*, *R. ficaria*, *Cardamine flexuosa*, *Lychnis dioica*, *Arenaria trinervis*, *Oxalis acetosella*, *Vicia cracca*, *Circæa lutetiana*, *Sanicula europæa*, *Dipsacus sylvestris*, *Nepeta glechoma*, *Rumex viridis*, *Arum maculatum*, *Deschampsia cæspitosa*, *Bromus asper*, etc.

The sandy beds are well distinguished by the occurrence of such plants as *Rumex acetosella*, *Aira præcox*, *Hypochæris radicata*, *Crepis virens*, *Linum catharticum*, *Cerastium triviale*, *Festuca ovina*, *Agropyron repens*, *Rubus rusticanus*, *Plantago media*.

The plants of alluvial ground are also very characteristic, consisting largely of marsh or wet meadow plants, chiefly of northern origin. The following are useful in the recognition of alluvium: *Spiræa ulmaria*, *Veronica beccabunga*, *Caltha palustris*, *Cardamine pratensis*, *Phalaris arundinacea*, *Poa trivialis*, *Apium nodiflorum*, *Juncus glaucus*, *J. effusus*, *Carex glauca*, *C. riparia*, *C. paludosa*, etc., *Alopecurus geniculatus*, *Geranium robertianum*, etc., *Mentha hirsuta*.

IV.—On Lifting by Ice-melting.

By the Rev. Edwin Hill, M.A., F.G.S.,
late Fellow of St. John's College, Cambridge.

EVERYONE knows that ice floats in water, is able to carry some amount of materials attached to it, and if lifted by rise of the water-level is able to lift them with itself. Lyell describes this in the *Principles* (ch. xvi, xxxi), and probably it is mentioned in every textbook. But ice is also able to lift attached materials without rise of the water-level. It requires no tides, no floods; it can lift without external aid, by its melting alone.

When a crust of ice 1 foot thick has formed on a sheet of fresh water it floats with its upper surface about an inch above water-level, its lower surface about 11 inches below.[1] If by any cause this ice-crust is melted over its upper surface, the products of melting flow off, the upper surface sinks a little, but the lower surface rises through about eleven-twelfths[2] of the thickness melted off. Take an ice-floe uniformly 6 feet thick: its lower surface will be floating, if the water be fresh, at about 5½ feet below water-level. Suppose it reduced by melting over the upper surface till only 6 inches thick, the lower surface will now be about 5½ inches below water-level; this lower surface will accordingly have risen more than 5 feet. If any objects or materials were attached to that lower surface they will have risen with it: they will have been lifted. This is undeniable and obvious. It is undeniable and obvious that ice is able to lift materials by simple melting, independently of any other power or action.

An ice-crust may be conceived as melted only over the upper surface. It seems not unlikely that most of the melting takes place

[1] With ice of sp. gr. ·918, ·984 inch above, 11·016 inches below. Captain Scott thought that the ice of Antarctic bergs may be much lighter (*Voyage of Discovery*, vol. ii, p. 411).

[2] 11·016 out of 12.

over the upper surface. Sun heat attacks only the upper surface; wind and rain attack only the upper surface; the flow off from melting will not for some time have any melting power. Even a warmer current, so long as water above freezing is denser than water at freezing, is likely to pass below the water in contact with the ice: the lower surface will be likely for a while to escape its influence. In considering only cases of melting from the upper surface we shall be considering, I think, a large majority of the cases which actually occur. That ice does melt on its upper surface every skater knows by experience of thaw, and accounts of Polar explorations describe summer alterations of the surface even in the regions of greatest cold. Wherever ice is formed melting must be very frequent. There are incessant alterations of temperature, by changes of wind and cloud, by changes of night and day, by changes of winter and summer. Melting is an action of very frequent occurrence. Lifting by melting must be a very frequent result. It may produce a variety of consequences, according to the variety of circumstances.

In shallow waters the ice-crust will, over parts, touch the bottom. Parts of the sodden bottom may, and doubtless will, be frozen to it, will when its surface melts be lifted by it, may when it breaks up and floats away be carried away with it. From a bottom undulating in ridges or mounds, if the ice be in contact with such ridges or mounds, the highest parts will be lifted and removed. Thus the depth will be made more uniform; the effect will be as if tops were planed away. The bottom will be levelled and the average depth increased. Ice melting and lifting is an agent of levelling and of denudation.

When the ice floats away materials attached to it will be floated away: the ice melting and lifting will become an agent of transportation. If a portion strands, where it rests the attached materials may rest. If a portion melts, where it melts the attached materials may be deposited. Ice melting and lifting will have become an agent of deposition.

When an ice-crust has enveloped any objects projecting from the bottom, as it rises it tends to pull them up. The lifting power of flotation is well known: it has been employed to tear up piles, barges lashed to them raising them with a rising tide. An ice-crust melting exerts the same action. Horizontal force on such objects would be resisted by the strength of the matrix in which they are embedded; but vertical lift is resisted only by their weight and adhesion. Ice melting and rising exerts the action which has been attributed to glaciers under the name of 'plucking', and exerts it in the most favourable direction.

When an ice-crust forms against a bank or cliff portions will adhere to it: portions may be broken away as it rises, and will be carried away if it moves. This action will steepen banks and undermine cliffs. It is the action which has been attributed to glaciers under the name of 'sapping'.

Ice melting and lifting will elevate. Boulders attached to its under surface will rise with that surface, and if stranded will be left at a higher level. The elevation by a single operation cannot exceed the thickness of the ice. But where land is sinking repetitions of the operation might elevate to the total extent of subsidence. Also, any snowfall will sink the ice by its superincumbent weight.[1] Should the periodic snowfall exceed the periodic melting the under surface will continue to sink. In an ice-age lakes thus easily may, probably will, become solid masses of ice. When milder times return materials from their very bottoms may be brought to their surfaces.

On land, when ice filling a rock-basin moves through it, materials may be moved from the lower levels to the level of outflow. But even when the ice does not move through, on melting it may bring up materials from the very bottom to the surface.

When an ice-floe with attached pebbles or rock-fragments strands, scratches and striations on pebbles, fragments, and bottom may result, as has often and long ago been suggested.

This action of ice-lifting by melting should produce its maximum effects in groups of conditions, different for different effects. For removal of material, planing down, denudation in general, the most favourable conditions while climate remains unaltered seem to be, a land undergoing alterations of level; either rising, whereby fresh bottom is being brought within reach of the ice, or sinking, whereby fresh stretches of margin are being submerged.

In lifting boulders to points above their place of origin, the greatest possible lift is from the lowest point reached by ice in the period to the highest.

For accumulation of a thick deposit favourable conditions seem, a wide area of shallow water alternately frozen and thawed, which should drain into an area of warmer water sufficiently deep.

The action described does not necessarily require a low mean annual temperature. Favourable conditions would be, severe winter cold, with summer warmth sufficient to melt ice at the surface and to break it up. The action would be vigorous during the incoming of a glacial period. When cold grew so severe that there was no summer break up the action might cease, but would recommence when the cold began to pass away. During every part of such period the action, though suspended over the interior of the cold area, would probably still be going on over the outskirts. Even now it must be going on in several parts of the earth.

The amount of work which could be done in this way might be considerable in a sufficient time. Thousands of years are claimed for the durations of ice-ages: if so, work done in them should be the average work of a year multiplied by thousands. An ice-raft able to support an inch of material would not need to be very thick. Anything attached to the lower surface would be buoyed up by the water and lose part of its weight. Consider material of sp. gr. 2·50. An inch-thick layer on the upper surface would require about 30 inches of ice, but if attached below could be supported by about

[1] Scott's *Voyage of Discovery*, vol. ii, p. 458. Shackleton's *Heart of Antarctic*, vol. ii, p. 289. Also Lyell's *Principles*, ch. xi (there of drifted snow).

20 inches only.[1] A 6 ft. thick ice-sheet, after three-fourths had melted away, could still transport a layer of nearly an inch.

"The thickness of floe ice in Baffins Bay is said to average 5 or 6 feet: elsewhere it is much thicker" (Bonney, *Ice-work*, p. 62). In the Gulf of Bothnia also it is 5 or 6 feet (Lyell, *Principles*, ch. xvi). In the Antarctic Captain Scott estimates it as "in exposed sea under 8½ feet; where land precludes rapid circulation of water as much as 10 feet by freezing alone; where snow accumulates any thickness may be produced" (*Voyage of Discovery*, vol. ii, p. 458). In Shackleton's *Heart of the Antarctic*, vol. ii, p. 277, the maximum thickness of sea ice is given as 7 feet.

If a Glacial period began over our present England, would not these effects be produced in such shallow sheets as some of the Norfolk Broads? If subsidence should also occur, the Fens and other low-lying tracts would experience the action. Many inland areas are broad and level; they, too, would be brought under it. Imagine the Vale of York water-covered while ice-age temperatures prevailed; would not much of its surface be lifted and carried into the Humber? Would not the Humber Estuary be kept filling up, and kept filling up with material like the matrix of the Holderness Clays?

Some peculiar features of some Glacial formations are what might be expected if this action had been at work.

Objects frozen to the bottom of an ice-crust, lifted and dropped without stranding, would suffer no friction, no abrasion, no crushing. Even should the ice strand, such objects being firmly frozen would be in circumstances favourable for escaping injury. Ice lifting from a bottom would lift its burden whole. By its thaw the most delicate shells might be deposited without chip or scratch.

In stranding, as has been said, objects attached to the lower surface might be scratched. Also at the beginning of flotation there would probably be some movement before complete removal. Such also would grind or scratch. In the Chalky Boulder-clay the pieces of chalk are mostly rounded, many scratched.

Sedimentation in moving water is expected, ordinarily, to increase in amount with the depth. Sedimentation from ice-rafts would not be governed by depth. It would depend on the distribution over the surface of such rafts, their loads, and their melting. If distribution were uniform, deposit would be uniform; it would cover the bottom with a mantle of uniform thickness over plateau and valley alike.

Material would be lifted in sheets, and might be so dropped. Sheets, streaks, and pockets are frequent in Boulder-clays. I find it easier to conceive even the long sheets of chalk in the Cromer cliffs to have been lifted and dropped, than to be consequences of displacement by thrust. Certainly, an ice-floe which could bear up a strip of chalk 120 yards long and 10 deep (there is one such near Runton) must have been large. But a floe twenty times its volume would be large enough, and what would that be in Polar seas?

This paper treats of an action which would go on under water

[1] This in fresh water. For salt water the necessary thicknesses would be less: about 25 and 15 respectively. With ice as light as Captain Scott's estimate they would be smaller still.

during an ice age. Other actions might go on under water, and others would go on at the same time over land above water. These are not considered here.

Lyell seems to have realized the action when he writes (*Principles*, ch. xvi, near end): "In . . . the Baltic . . . the surface freezes over to the depth of 5 or 6 feet. Stones are . . . frozen in . . . and lifted up on the melting . . . in summer." I have not noticed any other recognition.

The agency of ice forming on water and melting, gaining in thickness and losing, is thus able to denude, deepen, plane down, score, striate, 'pluck,' 'sap,' deposit, fill up, elevate, lift to heights. Not only is it able but it must perform these operations, whenever certain conditions combine. All these conditions have existed in the past, and now exist in separate regions of the earth: they can hardly be supposed to have never combined. Such an agency ought not, in speculations, to be altogether left out of account.

V.—The Boring at Heathfield, Devon.

By A. J. Jukes-Browne, F.R.S., F.G.S.

THE geological importance of this boring lies in the fact that it is the deepest which has yet been made in the Bovey Basin, that the site is nearly in the middle of that basin, and that it is evidence of the great depth of the syncline or trough in which the Bovey deposits lie. Although it did not reach the base of these deposits it is highly desirable that we should know the exact depth to which it was carried, as it is the only means of estimating the minimum depth of the basin.

An account of the boring was communicated to me in 1908 by Messrs. Candy & Co., of Heathfield, and was published in this Magazine for June, 1909. As the boring was made for Messrs. Candy and Co. at their Heathfield Potteries, and as they would naturally keep a record of the main facts, I had every reason to suppose that the account which they supplied was correct so far as it went. They informed me that the boring was commenced on the floor of their large open pit, and was carried down to a depth of 456½ feet. They also stated that the depth of the pit was, and is, about 70 feet, so that the total depth from the surface of the ground to the bottom of the boring would be 526½ feet. This agrees very closely with the statement which they had previously made to Mr. H. B. Woodward in 1900 and published by him in that year. There is no doubt that the record preserved at the office of the firm shows those figures as the total depth.

It was therefore with much surprise that I found quite a different account of this boring given in the recently issued memoir of the Geological Survey on *The Country around Newton Abbot*. In this memoir the chapter on Tertiary Deposits is written by Mr. C. Reid, and he seems to have ascertained that the boring was actually made by Messrs. Legrand & Sutcliff, who supplied him with more complete particulars of the strata which were traversed. According to their account the depth of the boring was only 400 feet and the depth of the pit at the time was only 56½ feet, consequently the total depth reached was only 456½ feet, not 526½. There is therefore a serious difference between the account furnished to me and that given by Messrs. Legrand & Sutcliff, but Mr. Reid does not mention the fact, so that readers of the memoir might imagine that he did not consider the discrepancy to be worthy of notice.

In reply to inquiry, however, Mr. Reid has informed me that he did not publish the account given him without trying to ascertain the facts on the spot; that he went to Heathfield and saw the manager of the potteries and the foreman who was in charge while the boring was being made. As a result he came to the conclusion that someone had confused the depth from the surface with the actual depth of the boring, and that the latter was only 400 feet deep from the floor of the pit, which was then only 56½ feet deep, but had subsequently been deepened to 70 feet.

On receipt of this information I felt it incumbent on me to make further inquiry in order to satisfy myself that this conclusion of Mr. Reid's was correct. Application to the Manager of Messrs. Candy and Co. did not produce any satisfactory result; it appears that the record possessed by the firm gives the figures which were communicated to me, and the Manager can only state that he has not been able to find any positive evidence to show that a mistake was made in constructing the tabular section.

On the other hand, Messrs. Legrand & Sutcliff, by whom the boring was actually made, are able to give more definite information. Asked if they could confirm the account printed in the memoir of the Geological Survey and if payment was received for only 400 feet of boring, their answer was in the affirmative to both questions. Consequently I am now satisfied that the actual depth attained by this boring was only 456½ feet from the surface of the ground, that the figures and particulars given me in 1908 were incorrect, and that the account based thereon and published in my paper on the "Depth and Succession of the Bovey Deposits" in 1909 is erroneous.[1]

It is desirable that this conclusion should be put on record, because if no explanation were made those who may hereafter take an interest in the matter would be faced with two inconsistent accounts of the boring, and might find it difficult to ascertain which was the correct one. The case is only one more instance of the curious errors which creep into the records of borings. One can only wish that it was obligatory on all those who have borings made to a depth of more than 100 feet to notify the fact to the Geological Survey Office, so that the results could be properly recorded at the time, and be preserved where they would be accessible to all geologists and engineers. Publishers are obliged by Act of Parliament to supply copies of all books to the British Museum, and it is really of greater public importance that the particulars of all such borings should be communicated to the Geological Survey Office.

[1] Since the above was written the Manager of Messrs. Candy & Co. has informed me that having looked up the charges for the boring he finds that they were for only 400 feet. He admits, therefore, that a mistake must have been made in compiling the account of the section preserved in their office.

VI.—Professor Walther's Erosion in the Desert considered.

By W. F. Hume, D.Sc., F.R.S.E., F.G.S.,
Director of the Geological Survey of Egypt.

In the *Cairo Scientific Journal*[1] the first chapter of Professor Walther's new edition of *Das Gesetz der Wüstenbildung* was considered in some detail. His second chapter, "Die Abtragung in der Wüste" (pp. 111–218), is no less stimulating to thought and replete in observation. He opens this section of his work with a statement of the facts which point to great climatic stability in Egypt during historical times. Two of these are specially mentioned. First, the presence of a small sack of salt in a grave of the Eighteenth Dynasty, the analysis of which agreed absolutely with that of the salt at present obtained from the lakes of the Wadi Natrun. This occurrence, according to him, proves that the same salt mixtures were being formed at periods 3,500 years apart. A statement as to the nature of the resemblances which lead to so wide a conclusion would have been of interest. Secondly, attention is also called to the total absence of water in the Tombs of the Kings since they were first excavated, pointing to the underground water having stood for many thousands of years at more than 50 metres below present valley level.

No doubt these conditions indicate climatic similarity, but other arguments, such as the opening of routes across the desert in early times, have been adduced in favour of a less marked aridity than at present exists. The question is one calling for much wider treatment than has yet been given it, but it is as well to have every thoughtful observation recorded as material for further discussion. The uniform character of the Nile alluvium, and the great development of the longitudinal dunes in the Libyan desert, certainly point to very little climatic modification during the historical period.

A long section is devoted to the erosion of Egyptian monuments by sand-blast, and as it is illustrated by photographs from the neighbourhood of the Pyramids it is of considerable interest to those dwelling in this country. So also are the pages in which Professor Walther regards the destruction of many of the monuments in Karnak and elsewhere as due to weathering through temperature variations, and not, as is commonly assumed, to earthquakes. The Memnon statues, for instance, built as they are of Nubian Sandstone cemented by siliceous material, and based on the Nile alluvium, are not readily liable to fracture by earth-movements, while they have been subject for many centuries to the great variations of temperature (insolation) by day and by night. The musical notes of the Memnon, which lasted for some two hundred years, are regarded by Professor Walther as due to the wind traversing one of these fractured portions, the sounds ceasing as soon as the statues were walled in by Septimus Severus.

Section 14 deals with "Dry Weathering" (Trockene Verwitterung). Attention is called to the very important activity of evaporation in the desert areas, by which many solutions present in the upper portions of the crust are being continually drawn to the surface, and

[1] *Cairo Scientific Journal*, No. 77, vol. vii, pp. 32–41, February, 1913.

there evaporated with deposition of saline and other dissolved constituents.

These are practically 'desert evaporation effects', and in spite of his statement that by the use of the term 'dry' he does not mean absolute absence of water, the title of this part of the section is distinctly misleading, though applicable to features dealt with later in the chapter. Futterer has given the name 'exsudation' to these phenomena, which appears preferable. The effects of these activities are manifold and everywhere obvious, and those who desire a careful study of this question in its economic aspects will find valuable details in Mr. Lucas's Survey memoir on the *Disintegration of Building Stones.*

In considering the effects of these evaporating solutions, attention is called to what the author terms 'mass-movements' in the rocks. According to him (p. 124) there have been upward movements of materials in certain cases, and as an example he mentions one of the stones in a wall on the west side of the Great Pyramid which has 'squeezed out' some 8 centimetres beyond the regular line of blocks of which it forms a part. He also cites cases of smaller fragments found on the surface, obviously splintered from the parent foundations, and now separated from them by several metres of made ground. It would be interesting to have the views of archæologists as to these anti-gravitational movements suggested for pottery and other objects of human construction embedded in soft muds.

A small section is devoted to the very beautiful 'rippled limestones' often found on the surface in the Egyptian and Atacama deserts. These were regarded by Abel as being fragments lifted into the air during heavy wind-storms, rotated rapidly, and etched on all sides by streams of blown sand. The size of the blocks seems, however, to exclude any such explanation. One would be extremely sorry to face a sand-storm such as would move the fine specimens now in the Geological Museum of Cairo. Beadnell, who collected these and described them as 'vermicular', justly called attention to the fact that these structures only occur (at any rate as a rule) in a hard grey crystalline limestone, and he connected their origin with drifting sand. According to him they would appear to depend on the internal structure of the rock rather than on any external conditions, but may perhaps be partly due to the irregular paths taken by sand grains in motion. Professor Walther points out that they occur both on angular and rolled limestone fragments, and these of very varied size, excluding, as above stated, the idea of movement. Where the 'Rillensteine' or ripple-stones lie on a clayey basis the ripples are sharp and resemble the solution figures which are produced when limestones are etched with weak acid. Calcite veins in the pebbles are more completely dissolved, and leave sharply marked furrows with a breadth at the surface of 1 to 4 millimetres. Where, however, sand is spread over the desert floor, or the surfaces indicate previous sand action, the ripples are smoothed down and disappear on the lee side. In digging down they are found with well-emphasized markings to a depth of 10 to 20 centimetres; in large fragments Professor Walther noted that the continuous ripples beneath the surface were clearly marked, but above it were smoothed, rounded, and polished.

He concludes that the 'ripples' or 'vermicular' markings are produced in the soil and near the surface through the action of concentrated solutions rising to the ground-level. As they slowly move along the side of the limestone fragments they produce linear markings. The removal of the clayey material reveals the etched surfaces, which are gradually worn down by the sand, while new ripple-stones are uncovered as the clay is removed by wind from around them.

There is always an advantage in having some explanation given for any phenomenon, because it at once arouses the critical faculty in the majority of mankind, and this tends to progress. Like Professor Walther, I have sought for an explanation as a solution effect, in which dew or rain, concentrated solutions of contained salts, and a particular rock-structure resulted in these curious markings.

Professor Walther is naturally also impressed with the changes on rock masses themselves resulting from the movement of highly concentrated solutions through them. In this connexion reference is made to the remarkable grape-like aggregations which are formed when finely divided carbonate of lime, clay, and quartz sand are moistened and subsequently become bound together under the influence of the sun's heat. He next turns to a question which has aroused much interest, viz. the origin of the gypsum present in enormous thickness near the Red Sea and elsewhere. Attention is called to Professor Natterer's observation that the waters of the Red Sea penetrate for long distances into the rocks of the shore-line, and there produce metasomatic changes. It is rightly pointed out that these regions are like a huge retort, in which remarkable chemical changes may be proceeding on a vast scale. Professor Walther frankly adopts the view that the gypsum is not a primary deposit, but represents the wall of the Erythræan depression, formed originally of marine limestones, but subsequently altered to gypsum.

In this connexion he calls attention to the pseudomorphs in selenite of bivalves, gasteropods, and corals collected by Dunn on an island south of Berenice. Far from this being an isolated case, examples are available from many parts of Egypt. At Abu Mingar there is a very interesting stratum in which a very inflated bivalve (*Diplodonta*) is formed of glassy-looking selenite; at Jemsa a bed of small *Corbulæ* is entirely replaced in gypsum, and the change can also be observed taking place in a limestone bed on Little Jemsa. The surface layers of calcareous strata are frequently altered to powdery gypsum, and Wade has called attention to the metamorphosis of the large basin shell *Tridacna* into the same material.

Nor is this the only case of formation of sulphates. The Survey Chemical Laboratory has examined many specimens collected by the Geological Survey, the analysis of which show that sulphates of alumina and iron play a most important role in desert deposits.

The change of ordinary limestone to a true dolomite by the action of magnesian salts is equally impressive. Sea-water breaking through the open-work structure of projecting masses of coral show replacement of this kind to a marked degree. The rapidity of chemical changes of this nature was illustrated in the Graving Dock at Alexandria. Certain curious coralloid-looking growths, formed along fissure-planes in the bottom of the dock, proved on examination in the Chemical Laboratory of the Survey Department to be compounds of magnesium and calcium carbonates, produced by the attack of the magnesium salts in the sea-water on the carbonate of lime in the concrete blocks.

On p. 128 et seq. the question of weathering under the influence of solutions rising to the surface is carried a stage further. By the crystallization of the salts fragments are split off the surface and, where exposed, are soon broken up and carried away. This is not, however, the case in cavities and wind-shaded spots. There the loosened plate-like portions attached to the parent rock, and, if they are hygroscopic, may contain sufficient water of solution still to be chemically active. This affords another explanation for the remarkable cavities developed in the granites of tropical regions, where their position is such as to exclude the direct action of wind-borne sand. It will require a chemical pronouncement to decide whether the contained salts in the weathered portions would be sufficient to produce the remarkable effects observed.

Professor Walther next considers the conditions which lead to fracture of rock masses, such as is commonly assumed to result from the influence of temperature variation. He illustrates the conditions observed by photographs of the 'melon' region of splintered flints in the Libyan Desert, and especially by some fine photographs of fractured granite and diorite blocks, the latter from the pass of Belowitak in the Ethiopian Hills. Here the diorite possessed most of the characteristic features of desert weathering. It has a deep brown surface film, the individual blocks have been fractured asunder into pieces whose former connexion is indisputable, the surfaces are breaking up into flakes arranged tangentially. The rocks have undergone no chemical alteration, but all around the foot of the huge boulders is a coarse gravel composed of small fragments of the rock, or where granite is present of small quartz and felspar grains.

Each of these characteristics, which combined are the true 'dry weathering', has its special method of origin, the most easy to explain being the tangential flaking, or desquamation (to use von Richthofen's term). When a boulder is warmed by day and cooled by night the effect of increase of volume due to the heating only extends to a small distance inward, the thickness of the surface affected depending on the nature of the rock. Gebel Kassala is given as an example of the remarkable smooth surface slopes covered with huge 'shells' separated from the parent mass and still only slightly attached to it, while around the base lie the shattered fragments of others loosened from their supports. Fig. 70, illustrating this feature, is somewhat disappointing. Plate xi in my Eastern Sinai memoir is a far more impressive example of these occurrences. Excellent illustrations are given of a fractured quartz grain and of a fracture mosaic on p. 61, while in studying this section the reader may turn back with advantage to figs. 25 and 26 for examples of 'pitted', 'flaking', and 'vertical' splitting.

The opinion is expressed that the best explanation of these phenomena has been given by Pechuel-Lösche, who ascribes them to the sudden cooling produced by a torrential rain falling upon highly heated surfaces. Attention is called to the intensity of physical change when rain at 20° C. or hail at 0° C. suddenly falls on rocks heated to 80° C. Numerous small cracks are produced due to cooling, subsequently often enlarged by temperature variations in blocks suitably exposed.

He also mentions the extraordinary cavernous weathering exhibited by rocks of heterogeneous composition and variety of mineral colouring, such as the granite (see fig. 73). The variously coloured constituents expand with varying rapidity under the solar influence, and also in cooling contract at different speeds. This constant interplay causes a loosening of the individual particles, so that it is very difficult to obtain a solid specimen of typical red granite or other igneous rock in the Red Sea Hills or Sinai. To this breakdown he ascribes the frequency of sand-slopes among the granitic hills, the wind sorting out the materials, the quartz remaining to form the dunes, while the mica is swept onward into protected places and the felspar rapidly breaks up into cleavage fragments.

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

REVIEWS.

I.—The Coal Resources of the World: an enquiry made upon the initiative of the Executive Committee of the Twelfth International Geological Congress, Canada, 1913, with the assistance of Geological Surveys and mining geologists of different countries. Edited by William McInnes, B.A., F.R.S.C., D. B. Dowling, B.A. Sc., F.R.S.C., and W. W. Leach, B.A. Sc., of the Geological Survey of Canada. 3 vols. Crown 4to; pp. 1266 + civ, with plates and illustrations in the text and accompanied by an atlas of maps. Toronto, Morang & Co.; London, Dulau & Co.; 1913. Price £5 5*s*.

It is a truism that a deposit of iron-ore is of no value if there is no supply of coal. This comprehensive and valuable work, chiefly written in English, therefore forms a fitting sequel to the monograph on the iron-ore resources of the world issued by the Eleventh International Congress in 1910. The present volumes, in a series of articles written by experienced geologists and mining engineers, afford valuable information about all the known coal-bearing regions of the world. In the case only of Greenland, Peru, and Brazil has it been necessary to compile from published literature, so that the monograph affords the latest and most authoritative pronouncement on the "coal resources of the world" and replaces all previous literature on the subject.

To review adequately such a large amount of information is here impossible; a brief résumé of the general scope of the work, with mention of a few of the more interesting and striking features, is all that can be attempted.

Tables giving the Actual, Probable, and Possible Resources for the individual countries and districts naturally occupy a prominent place, but generally they are accompanied by a geological description, amounting in some cases to a thesis on the subject, and containing much new matter of great interest to the geologist. To ensure uniformity the different types of coal are entered in several classes, which correspond roughly to (A) anthracite and dry coals, (B and C) bituminous coals, (D) sub-bituminous coals, brown coals, and lignite.

The tables of production show at a glance the scale on which individual countries are at present engaged in the industry, the United States easily heading the list, seconded by Great Britain, but followed very closely by Germany. In all these the annual production reaches hundreds of millions of tons, while none of the remaining countries reach an output of forty millions of tons.

A useful summary and digest of the Reports is given, a task which must have seriously taxed the editors, as some of the contributions did not reach them until the middle of May, 1913. For this reason "the latest reports, being longer than anticipated, had to be hurriedly condensed, and many illustrations and maps not adapted for direct reproduction in the form in which they were received had to be omitted". It would be obviously unfair, therefore, to criticize the character of the text-illustrations and of the plates given in the atlas, but a great divergence in colouring and execution is noticeable. The omissions, however, are not serious.

The coal resources of the world are given as 7,397,553 millions of metric tons, and the annual production as 1,143·38 million tons. A worldwide shortage of fuel evidently lies a long way off, though a considerable reduction in this colossal amount of coal must be allowed for loss in mining, for seams not at present mineable, and, what is more important, for seams mineable but not at a profit. Individual estimates also differ so enormously that some are openly little more than guesswork.

The world's supply is at present largely drawn from the later Palæozoic formations, but it is well to be reminded that equally rich and valuable seams occur in the Mesozoic and Tertiary formations, both in the Old World and in the New.

Taking the separate countries in the order in which they are dealt with in the volumes;—

The account of Oceania is given in much detail, and includes the new coal-fields of Antarctica.

In Asia, besides accounts of the lesser coal-fields, we have the latest information about Japan and China. The latter, true to tradition, has mined coal for several thousands of years, but so slowly does she advance that out of 38,765,000,000 tons of probable, in addition to 'enormous' possible reserves, she extracts, mostly due to foreign enterprise, only 18 million tons per annum. It is evident that many geological problems still await solution, as the following extract (vol. i, p. 210) will show: "In Ssŭ-ch'uan-shêng, Kuei-chow-shêng, and Yün-nan-shêng, the basement complex of the region consists of phyllite, sandstone, and limestone, considered to represent the Devonian and Silurian. The lower part of the thick limestone which overlies the formation is of Devonian age, while the upper intercalates shale, sandstone, and quartzite with coal-seams, and represents the Carboniferous and Permo-Carboniferous. Another heavy limestone formation, with red shale in the middle and diabase sheet in the lower part, rests on it, and also contains coal-seams. It is the Permo-Trias. Most of the coal-seams in Kuei-chow-shêng and Yün-nan-shêng are interbedded in these two formations." Truly a Chinese puzzle.

Japan's contribution is a memoir in itself, well illustrated by maps and diagrams in the text, and by several artistically coloured and delicately outlined maps in the atlas. The statement (vol. i, p. 296), coming from one in a position to judge, that Japan will satisfy the demand for coal in the circum-Pacific country for many hundreds of years, particularly arrests attention.

The chief African coal-fields, as is well known, occur in the south, and the information supplied about the other still imperfectly known coal-bearing districts in Central Africa shows that the continent is not over abundantly supplied with coal. Northern Africa, except parts of the Nigerian Protectorate, appears to be almost destitute of coal other than patches of lignite.

The account of the great coal-fields of Canada, illustrated by eight maps in the atlas and by eight figures in the text, affords a useful summary of an important and rapidly growing industry. In the far north, as well as in other northern regions, deposits of coal are widely distributed.

A map in the atlas, showing the distribution of the coals according to class, in conjunction with six pages of tabular matter in the text, brings prominently into view the vast resources of the United States. Of the coal supplies of South America the available information is evidently still meagre and uncertain.

The reports by the leading authorities on the European coal-fields occupy 552 pages of printed matter, abundantly illustrated by maps and diagrams and accompanied by no less than twenty maps in the atlas.

In Holland a great thickness of unproductive cover shows how much of its coal lies hopelessly beyond reach.

In Great Britain, while an area of 206 square miles in the concealed coal-field of Kent is included for the first time among the estimates for this country, 760 square miles is substituted for one of 2,550 square miles for the unproved area in Yorkshire and Nottinghamshire. This reduction has been made in conformity with explorations in the valley of the Trent between Nottingham and the Humber, completed since the Report of the Commission in 1905, and of which the results have been published recently (1913) in an official memoir.

This great change in the estimated resources of one of the most highly developed coal-fields in the world shows that it is necessary to exercise great caution in accepting too literally the figures given for imperfectly explored regions.

II.—Igneous Rocks. Vol. II. By J. P. Iddings. 8vo; pp. xi, 685. New York: Wiley and Sons, 1913. Price 25*s*.

WHEN it was announced a few years ago that a group of distinguished American petrologists had decided that the time was come to reform the classification and nomenclature of igneous rocks most students of petrology looked forward with interest to the appearance of a textbook showing how the new classification actually worked out in practice. The most severe and final test of such a proposal would thus be furnished. Professor Iddings' textbook, however, does not meet this demand. It runs very much on the old lines, the 'qualitative' system, so heartily condemned, serving as the basis on which the rock groups are arranged, while the 'quantitative' classification appears only in short appendices to the chapters, printed in small type, and very interesting, but far from complete.

This treatment makes the book much more valuable to the student preparing for examination. All the well-known varieties of rocks are described under six divisions according to their component minerals, from those which consist mainly of quartz, to the ultrabasic rocks such as the pyroxenites and peridotites. Each group is subdivided into (*a*) phanerites (coarsely crystalline), and (*b*) aphanites (finely crystalline or partly glassy). Chemical analyses are given mostly in separate tables. The new American names appear seldom except in short discussions of the grouped analyses, and the 'mode' instead of the 'norm' is the dominant factor in the classification.

One merit of this textbook is that it is well abreast of the times, and the new rock-species recently described from districts such as the Urals, Finland, and Western North America obtain recognition, and at any rate a brief definition. The author occasionally, though all too seldom, gives us a criticism of the validity of the older names such as theralite and essexite (pp. 231 and 247). The first part of this volume, containing the description of the rocks, is only 330 pages, much too short for adequate treatment of the subject, and is hardly sufficient for more than a definition of the established rock-names. It reads very much like a catalogue, and the 'microscopic physiography' of the different rocks receives little notice. Within its limits, however, the book is excellent, and should be in the hands of all senior students of petrology.

The second part of the book describes the occurrence or rather the distribution of igneous rocks. We have read it with great interest, as it provides a valuable summary of what is known regarding the igneous rocks of all parts of the world. They are grouped under geographical provinces such as North America, South America, and Europe, and an attempt is made to define also the geological age of the rocks described. Moreover, fairly full references are given to the literature, and a useful set of maps is provided to show where the rocks are situated. Professor Iddings is sceptical about the value of 'petrographical provinces', and he lays down criteria which, in our opinion, are unnecessarily rigid (p. 346). It is sufficient for the meantime if we can recognize that the rocks of certain districts belonging to a certain epoch have well-marked characters which distinguish them from, or relate them to, those of other districts or epochs. The problem is a very large one and does not admit of very rigid treatment in the present state of our knowledge or ignorance. It seems to us that no more convincing argument in favour of the views of Judd, Harker, Prior, and Becke, has ever been brought forward than Professor Iddings' calm and impartial summary of the facts. The contrast furnished by the volcanic rocks of Africa, mainly 'alkali-rocks', with a few andesites in the north-west part of the continent, with the andesitic volcanoes of Japan, with a few centres of alkali rocks on the western side, is as striking as the difference between the broken plateau of Africa and the ridge-folds of Japan. It is true there are many exceptions and anomalies, but these do not affect the main issue. They show merely that there is much work to be done in this field, many types and sub-types still to be defined and established, and many disturbing factors to be taken into account. It lends a new interest to petrology which seemed about to lose itself in a wilderness of descriptive material, endlessly varied, but leading to few wide generalizations. The application of exact methods to the experimental synthesis of rocks and minerals and the study of magmas in relation to the physical history of their province are the most notable advances of the science of petrology in recent years.

The second part of this volume, accordingly, is of the greatest importance to students of petrology. Professor Iddings has spared no labour to become acquainted with the facts at first hand, and he marshals them in order and places them clearly before us. Many small inaccuracies might be pointed out in the chapter on British rocks, but these are mainly due to the imperfection of the descriptions given by the older writers on the subject. The volume fills an important gap in the list of books required by the student of rocks for his daily work.

J. S. F.

III.—Mountains: their Origin, Growth, and Decay. By James Geikie, LL.D., D.C.L., F.R.S., etc., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 8vo; pp. xix, 313, with 81 plates and 57 text-illustrations. Edinburgh: Oliver & Boyd. Price 12*s.* 6*d.* net.

SINCE the publication in 1886 of T. Mellard Reade's *Origin of Mountain Ranges* there has not been issued in this country any work dealing exclusively with this subject from a worldwide point of view, although of course a mine of information is to be found in the monumental work of Suess, *Das Antlitz der Erde* (English translation, 1904–9). Of more recent works those on *The Building of the Alps* by Professor Bonney, and *Earth Features and their Meaning* by Professor W. H. Hobbs, both published in 1912, have been noticed in the Geological Magazine. The subject in those two volumes is dealt with in a manner less severely scientific than that of Mellard Reade, and this is the case with the handsome and profusely illustrated volume before us. As remarked by Professor Geikie, all that he has attempted "is such a comprehensive sketch as may be helpful to readers not specially versed in Geology, who desire a fuller statement of the subject than is usually presented in geographical text-books". Technical terms have been avoided as far as possible, but a glossary is given in the appendix. The type is bold and clear, and there are few footnotes.

The author does indeed take a very comprehensive view of his subject. Professor Hobbs, in defining a mountain, remarked that the word is "applied to a feature of the earth and not merely to an elevated tract", as in the case of high plains; "their summits need not be at great heights above the sea, but it is essential that they project above the average level of the surrounding country by at least a quarter of a mile." To this or any other definition no strict adherence is made in geographical works, "elevations of the same height being called hills in one locality and mountains in another." The Malvern Hills, for instance, form a true mountain range in point of structure, and, as Professor Geikie observes, even diminutive hills must sometimes be put "into the same class with the loftiest mountains of upheaval". We find therefore that, in elucidation of his subject, the author more or less briefly describes various mounds and low hills of glacial detritus or wind-borne sand. His general grouping of hills and mountains is: I. Original or Tectonic; II. Subsequent or Relict mountains.

The Original or Tectonic mountains are classed as (1) those due to Accumulation, and (2) those due to Deformation. We are brought first to consider the eminences due to volcanic accumulations, and the subject is illustrated by many text-figures and fine plates. Here it may be mentioned that the term 'cone-in-cone' is applied to small and younger cones within a more extensive eroded crater-ring or caldera; but the term is more usually applied to nail-head spar or fibrous calcite, and to peculiar concretionary and crystalline structures seen in coal. Geyser sinter-mounds, moraines and other glacial features, and sand-dunes now come in for attention, many of these being of less altitude than the artificial Silbury Hill or the 'tips' from mine-works.

Passing on to the Deformation mountains, we come to the main portion of the subject, one which concerns "nearly all the more prominent ranges and chains of the globe". Three types are recognized, namely, Folded, Dislocation, and Laccolith mountains. The author's object is to give particulars of the geological structure, discussing theories of uplift and the origin of the features, without dwelling much on the scenery. This last-named topic is, however, well illustrated by the beautiful plates, produced mostly from photographs taken for the Scottish branch of the Geological Survey.

The various types of folding and dislocation are clearly explained, with the aid of diagrams and sections, as well as by photographic views of rock-structures seen in hand-specimens and in exposed rock-masses. The author observes that "To-day the prevalent belief is that deformation of the crust has probably as a rule taken place slowly and gradually, and that erosion and denudation have necessarily accompanied the elevation of mountains, so that throughout the whole period of their growth or upheaval they have been subject to continual degradation". This is no doubt true enough, but the effects of earth-movements on the shapes of valleys, as indicated by Professor J. W. Gregory in his work on fiords (see Geol. Mag., December, 1913), has not always been sufficiently considered. How greatly disturbances have influenced the physical features is shown in the present volume in some of the sections of the Vosges, Alps, Western Jura, and Uinta Mountains.

There are grand views of mountain peaks and others showing the influence of weathering agents on different rocks, as in the Dolomite mountains; the influence of joints, columnar, tabular, etc.; of sills and laccoliths, batholiths or bosses, as in the Skye plateaus and mountains, the latter generally known as the Cuillin and Red *Hills*.

One chapter is devoted to an account of the leading geological phenomena of the Pacific Ocean and its coast-lands, and the author expresses his opinion that "Although it is not possible to demonstrate that the Pacific Ocean is of primeval antiquity, yet all the phenomena seem to favour that conclusion, and to negative the idea of a great Pacific continent such as the geosynclinal theory desiderates".

The Subsequent or Relict mountains include those carved out of plateaus of accumulation, such as the basalt plateaus of the Inner Hebrides, the heights of Saxon Switzerland, the tabular mountains of North African deserts, the Buttes of Wyoming, and the Bad Lands of Nebraska, as well as other escarpment heights and the features connected with cañons. It is admitted that some laccolith heights and many volcanic 'necks' must be regarded as Relict mountains, but, as the author observes, it is usually difficult, when dealing with Nature, to draw hard and fast lines.

IV.—The Evolution of the Cretaceous Asteroidea. By W. K. Spencer, B.A., F.G.S. Phil. Trans. Roy. Soc., ser. B, vol. 204, No. 306, pp. 99–177, pls. 10–16, 1913.

The work of Mr. W. K. Spencer on the Cretaceous Asteroidea, published during the last few years in the volumes of the Palæontographical Society, has been done chiefly from the systematic point of view. Much light has been thrown on the subject by his philosophic treatment in the present paper of the evolution of the group. A clear and useful summary of the aims of the essay serves as an introduction to the author's results, which are arranged under three headings, dealing respectively with the description of the 'species series', stratigraphical conclusions, and variation and evolution. Eight new genera and one new subgenus are established, and the classification adopted is that of Perrier.

The Cretaceous rocks not only of England but also of many important Continental districts have been considered, and from the stratigraphical point of view the results are satisfactory. The author finds that the Asteroid fauna could be used as a basis of horizonal classification, and that isolated ossicles are of value for zonal purposes. In the Upper Chalk of England the distribution of the Asteroids shows the zoological break at the top of the lower third of the *coranguinum* zone that was observed by Dr. Rowe in the case of the Echinoids. For this reason, as Mr. Spencer thinks, it would be convenient to adopt the suggestion of Messrs. Brydone and Griffith to include this lower part of the *coranguinum* chalk in the zone below. As regards the Upper Chalk, too, the author was led independently to recognize the existence of two separate stages, which were subsequently established by Mr. Jukes-Browne (Geol. Mag., Dec. V, Vol. IX, pp. 304–13, 360–72). The paper contains interesting observations with respect to the depth at which the various deposits were laid down, and the remarks on the Starfish fauna of the *cuvieri* zone at Branscombe (Devon) bear out the views of Messrs. Jukes-Browne and Rowe that a Greensand ridge existed in the neighbourhood of the Hooken, as is shown also by Sherborn.

Measurements of numerous ossicles have been taken with a view to discussing variation. It is shown that isolated supero-marginal ossicles can be taken as trustworthy indications as to the size and relative height of the individual. It is probable also that a high ossicle may represent some physiological advantage to the starfish, since the marginalia border the visceral cavity, and therefore an increase in height would allow greater space for the digestive organs and the gonads. In considering variations in a lineage Mr. Spencer adopts as a unit the tangent of height to length (of a supero-marginal ossicle), which he calls the ossicular angle, and the results are expressed graphically. The continuousness of variation shown to exist would render zonal work difficult but for the coexistence of other independently variable characters. Periodic elaboration, to which attention has been drawn in other groups by Bernard, Buckman, and Lang, is also traced. All races pass through parallel stages, and some variations must be regarded as predetermined; of some, in fact, the course could be predicted.

Apart, however, from its theoretical interest the paper has great practical value in that the collector can determine with a degree of certainty the isolated ossicles that are commonly found. Considering the unpromising nature of the material, Mr. Spencer's results are extremely encouraging to the palæontologist.

V.—United States Geological Surveys.

1. Coal Fields of Grand Mesa and the West Elk Mountains, Colorado. By Willis T. Lee. pp. 237, with 21 plates and 37 figures. Bulletin 510. 1912.

THIS bulletin contains a description of all the mines in the various districts and a discussion of the general geology and stratigraphy, illustrated by a geological map on the scale of 2 miles to the inch. The section on the quality of the coal contains over eighty analyses of samples.

The coal-fields of this area occur on the southern edge of a great basin in Western Colorado and Eastern Utah. The lowest beds exposed are shales and sandstones of the Gunnison formation, regarded as Jurassic in age. An unconformity separates these beds from an Upper Cretaceous series, which attains a thickness of some 6,000 feet and includes all the coal-bearing beds. The base of this series is formed by the Dakota Sandstone, which is overlain by the Mancos shale, containing coal of poor quality near the base, and fossils belonging to the fauna of the Montana group. The Mancos shale corresponds to the Montana and Colorado formations of earlier writers, Eldridge's Fox Hill division being represented by a transitional zone between the Mancos shale and the overlying Rollins Sandstone. The rest of the Upper Cretaceous rocks, about 2,900 feet, are represented by: (1) the Rollins Sandstone, containing *Halymenites major* and *Inoceramus*; (2) the Bowie shale, coal-bearing throughout, with marine and brackish-water shells; (3) the Paonia shale, also coal-bearing but characterized by abundant plant-remains and freshwater shells; (4) an undifferentiated thickness (2,000 feet) of sandstones and shales with plant-remains and freshwater shells, but containing only a little poor coal. The Bowie shale is absent in the central part of the Grand Mesa field, and elsewhere in the area it is separated from the Paonia shale by an unconformity.

The lower part of these Cretaceous beds was classed by the geologists of the Hayden Survey of 1881 as Fox Hills Sandstone, the upper part as Laramie formation: the invertebrate fauna, however, indicates that they may now be correlated with the upper part of the Mesaverde formation of South-Western and North-Western Colorado. The evidence of the plant-remains from the freshwater beds above the unconformity is less conclusive, and accordingly Mr. F. H. Knowlton's notes on the flora are given in detail. He concludes that the Paonia shale is certainly of post-Montana age and that it may prove to be Laramie or even still younger.

The Cretaceous rocks are overlain unconformably by the Ohio Creek conglomerate which Eldridge regarded as Cretaceous but which is now shown to be Tertiary. Another unconformity separates this from the Wasatch and Green River formations, a series of unfossiliferous sandstones and shales, probably Eocene.

The igneous rocks of the area were described by Whitman Cross in 1894. They comprise great laccoliths of quartz-monzonite porphyry of Tertiary age, basalt flows, possibly early Pleistocene, and a great development of andesitic breccias.

The burning of coal at the outcrop is the subject of an interesting note. This is less general on northern soil-clad slopes than on the dry southern faces of the hills. No evidence was found in favour of the theory of spontaneous ignition, and it is thought that the burning of the coal is due to forest fires.

In many places no coal appears at the outcrop, and quite the most striking point in the book is the evidence of the fossils on the nature of the buried coal which a prospector may expect to find at a given locality. It is pointed out that the high-grade bituminous coals are associated with the marine Bowie shale, characterized by *Halymenites major*, *Inoceramus barabini*, *I. sagensis*, *Cardium speciosum*, and *Ostrea subtrigonalis*; on the other hand, low-grade bituminous or sub-bituminous coals are found in the freshwater Paonia shale containing freshwater shells and plant remains. Seven splendid plates depict the most characteristic and easily recognizable fossils from the coal-bearing beds. This forms only one of many instances in which the United States Geological Survey have demonstrated the very close relation of purely scientific to economic geology.

2. Geology of Alaska.—We have received six bulletins relating to this territory, all published in 1913. No. 526 is on the "Coastal Glaciers of Prince William Sound and Kenai Peninsula", by Messrs. U. S. Grant and D. F. Higgins. This is well illustrated by maps and pictorial views, and "is intended to supply some definite information regarding the present positions and fronts of the glaciers, and the more evident facts of their fluctuations", with the desire also of attracting attention "to some of the most magnificent American scenery that is now accessible to the tourist and nature lover".

Five other bulletins contain descriptions of the geology, and especially of the placer deposits, of various parts of Alaska, and they will be invaluable as guides to prospectors and to further mining enterprises. No. 532, on "The Koyukuk-Chandalar Region", by Mr. A. G. Maddren, deals with a portion of the Yukon river-flats and of its tributary the Koyukuk. No. 533 is on the "Geology of the Nome and Grand Central Quadrangles", by Mr. F. H. Moffit, who describes an area in the southern part of the Seward Peninsula. It is remarked that "Bonanza mining in the Nome region, which has produced over $50,000,000 worth of gold, is now nearly a thing of the past", but the record is "of one of the richest placer camps of Alaska". Nevertheless the prospects of further profit are by no means discouraging; there are still "large bodies of auriferous gravels, many of which can be profitably exploited", while "the field is well worthy of careful prospecting for vein deposits". Although gold only has been mined with profit, small quantities of lode and placer tin have been obtained, and the occurrence also is noted of silver, lead, tin, bismuth, antimony, tungsten, copper, and mercury, in bed-rock and gravel deposits. No. 535 contains "A Geologic Reconnaissance of a Part of the Rampart Quadrangle", by Mr. Henry M. Eakin. This area lies along the Yukon River above Tanana town, and extends to the tributary valley of the Tanana River at Hot Springs. Gold occurs in the modern stream deposits and in the older terrace or bench gravels, but no other mineral has proved to be of economic importance. No. 525 is a "Geologic Reconnaissance of the Fairbanks Quadrangle", by Mr. L. M. Prindle, with assistance from Mr. F. J. Katz and Mr. Philip S. Smith, and is the most elaborate of the reports before us. The area adjoins that of the Rampart Quadrangle, extending higher along the course of the Tanana River. The report indicates that the placer-gold reserves are still very large, but that a great expansion of the industry in this field "can be brought about only by lessening the operating costs through improved means of communication". There are favourable prospects also for lode-mining, though at present the alluvial deposits have furnished practically all the gold. "Silver occurs as an impurity in the placer gold." It is remarked that most of the alluvial deposits are frozen throughout the year. No. 534 contains an account of "The Yenta District", by Mr. Stephen R. Capps. The Yenta River is a tributary of the Susitna, which flows into Cook Inlet on the southern side of Alaska. The Alaska Mountains lie to the north-west, and it is remarked that "the assignment to the Tertiary instead of to the Quaternary of the heavy gravels which mantle the foothills on both sides of the Alaska Range will necessitate considerable change in the published interpretations of the physiographic history of Central Alaska". The stream-erosion in Tertiary times concentrated some gold in the old river beds, but none in the Eocene lignite-bearing deposits which underlie the Tertiary gravels. There are no valuable auriferous lodes in the region, the placer gold alone proving of economic importance.

These reports are well illustrated by geologic and topographic maps, by views of scenery, rock-structure, and mining works. They contain descriptions of the physical features, climate, drainage, and water supply, of the animal and vegetable life, including the distribution of timber, with remarks on the means of communication (transport and supplies).

The lode-deposits are developed in the metamorphic rocks, with which are associated intrusive (mostly unaltered) granites and diorites that are possibly of Jurassic age. It is considered that these intrusive masses "have influenced the gold-bearing mineralization". The schistose rocks are grouped as Pre-Ordovician?; and in some areas there are also Ordovician, Silurian, Devonian, Carboniferous, and Cretaceous formations. The Tertiary lignite beds appear to be of little value except as a source of local fuel.

Much gold in the placer deposits has been reconcentrated from the Tertiary gravels, and some from Glacial deposits. Gold worked with profit in the gulches has been derived from the weathered vein-material of the bed-rock, and the deposits are termed residual placers, most of the material being not far removed from the parent source. The chief sources of the gold are in the lower-lying alluvial gravels. In the deeper deposits shafts have been sunk 200 to 300 feet, and where the deposits are solidly frozen steam is used to thaw them. In the higher bench placers gold is generally present and is locally sufficiently rich to be mined with profit. In the Nome area of Seward Peninsula there is much coastal-plain or tundra gravel, with beach placers, some of which are buried beneath the coastal-plain gravel, while others belong to the present beach: these in places are rich in gold. The gravel-plain placers "are small, and although one or two have yielded considerable gold, no very rich ones have yet been found" in the area. It is remarked that dredging promises to play an important part in the future development of the Nome district.

3. Geology of Idaho.—Bulletin No. 528 (1913) is on the "Geology and Ore Deposits of Lemhi County, Idaho", by Mr. Joseph B. Umpleby. The geological map shows the area, which is in the east-central part of the State, to be composed of Archæan gneiss; Algonkian quartzites, schists, and slates; Palæozoic (not separated), including Cambrian quartzite, Ordovician, Silurian (?), Devonian, and Carboniferous dolomites and limestones. There occur also Cretaceous or Tertiary quartz-diorite and granite, Tertiary lavas (rhyolite, andesite, etc.) and lake-beds, and glacial drift. The ore deposits include gold placers and lodes, lead-silver veins and tabular replacements, copper-bearing gold-veins, cobalt-nickel deposits, and tungsten-bearing veins.

The most important and older gold-veins are of late Cretaceous or early Eocene age, and appear to be genetically related to the great granitic intrusion. The younger gold-veins are enclosed in eruptive rocks, principally rhyolites.

VI.—Indo-China.

YET another large area of the unknown geological world has been explored by our friends and neighbours, whose labours are being made known in the Mémoires du Service géologique de l'Indo-chine. Of these beautiful publications we have received vol. i (fasc. i), *Étude géologique du Yun-Nan Oriental*, by J. Deprat and H. Mansuy, 4to, pp. 370, and nineteen exquisite plates of views and one of rock-sections, with accompanying atlas of 178 sections and many maps. Fasc. ii, by H. Mansuy, deals with the palæontology (Cambrian to Trias, Tertiary Lignite and Quaternary), and contains twenty-five excellent plates by Mémin of Arcueil (Seine); fasc. iii, by J. Deprat, is *Étude des Fusulinidés de Chine et d'Indochine et classification du Calcaires à Fusulines*; and fasc. iv treats of Laos and Tonkin in the following papers: "Géologie des environs de Luang-Prabang"; "Mission Zeil dans le Laos septentrional, résultats paléontologiques"; and "Contribution à la géologie du Tonkin, Paléontologie", all by H. Mansuy; the last illustrated by a series of similarly beautiful plates.

All these works seem to have been printed in Hanoi-Haiphong and published in 1912, and it gives us peculiar satisfaction to call the attention of the specialist to so rich a series of reference memoirs on Far Eastern Asiatic fossils.

VII.—Natural Sources of Energy. By A. H. Gibson, D.Sc., Professor of Engineering in the University of St. Andrews, at University College, Dundee. 8vo; pp. viii, 131, with 17 illustrations. Cambridge: at the University Press, 1913. Price 1*s.* net.

IN this little volume questions of general and worldwide interest are discussed, some of them having a direct bearing on matters of economic geology. The depletion of fossil fuels is in the first place considered, and reference is made to the probable life of British coal-fields, the lowest estimate being 175 years. Taking the most recent available estimates for the world, the entire supply is reckoned to be about 4,000,000 million tons. These immense quantities of coal, at the present rate of consumption, and "allowing for 33 per cent of wastage, would last some 2,500 years; whereas should the consumption keep on increasing at the same arithmetical rate as during the past five years they would be exhausted within 350 years".

With regard to oil fuel, while it is held by some authorities that "the manufacture of oil in Nature's laboratory" is still in progress through "the action of water vapour under high pressures upon various metallic carbides", yet it is considered that depletion would be more rapid than the manufacture. Indeed, the author expresses the opinion that "the oil-bearing strata will be exhausted long before our coal-fields".

After considering the questions relating to natural gas and peat, the author turns attention to other sources of energy, to radium, to the radiant heat from the sun, the heat energy stored in the earth, that to be obtained from certain vegetable oils, timber, and alcohol, and finally to the energy of rivers, waterfalls, tides, waves, and winds. In his concluding chapter he remarks that "to our present knowledge, even when the fossil fuels are exhausted, ample supplies of energy, renewable year by year, will remain for all the conceivable activities of the human race". Nevertheless, with regard to Britain, he considers that "the prospects of maintaining our present supremacy as an industrial community in competition with other regions more favoured by nature, are remote", and the probability is that "the coming ages will see a gradual drift of the industrial centre of gravity of the world towards warmer climes where, at all events, the necessity for artificial heating for domestic purposes will be largely non-existent".

VIII.—The Fertility of the Soil. By Edward J. Russell, D.Sc., Director of the Rothamsted Experiment Station. 8vo; pp. viii, 128, with 9 plates. Cambridge: at the University Press, 1913. Price 1*s*. net.

THERE is no doubt that interest in the scientific aspects of agriculture is largely on the increase among those engaged in the cultivation of the land, and the little work before us is admirably adapted to stimulate that interest. From a geological point of view, however, there is little that calls for remark; there are brief accounts of the general characters and origin of soils, but the work is mainly occupied by a description of how plant food is made, of the chemical, physical, and organic influences at work in the soil, and of the methods of increasing fertility. The volume is clearly written and contains interesting accounts of agricultural operations in olden times, of drainage, reclamation, and manures; and there is a view of the chalking of land in Hertfordshire, the material being still obtained in places by sinking a shaft down to the Chalk formation, where it is covered by clay-with-flints and drift deposits.

IX.—Prehistoric Society of East Anglia.—The third part of the Proceedings of this Society (vol. i, 1913) is a volume of 138 pages, with more than 40 plates, and it contains 19 articles. Among these are one on a tumulus on Achill Island, another on pygmy implements from Cornwall, and a third on stone implements from Western Australia. The policy of publishing papers dealing with regions outside East Anglia may be questioned, as the topics would be more appropriate for a local Archæological Society. The subject of patination is discussed by the President, Dr. W. Allen Sturge, and illustrated by plates, in duplicate, showing patinated and unpatinated sides of implements. Mr. J. Reid Moir describes flint implements from the Middle Glacial gravel and Chalky Boulder-clay of Suffolk; and Dr. Marie Stopes gives an illustrated account of the Red Crag shell portrait (see GEOL. MAG., 1912, pp. 285, 334). Among other articles is one on "The Problem of the Eoliths", by Mr. F. N. Haward, who thinks that "very few are humanly chipped".

X.—NORFOLK AND NORWICH NATURALISTS' SOCIETY.

AN interesting and instructive article on "The Topography and Vegetation of the National Trust Reserve known as Blakeney Point, Norfolk", by Professor F. W. Oliver, F.R.S., and Dr. E. J. Salisbury, F.L.S., has been published in the Transactions of this society (vol. ix, pt. iv, 1913). The Topography, by Professor Oliver, is of considerable geological interest, as it deals with the changes which have affected the coast. This comprises a shingle spit which leaves the shore near Weybourne, and extends about eight miles seaward slightly N. of W. On the landward side is the tidal inlet known as Blakeney Harbour, which at Cley receives the waters of the River Glaven. The area includes Blown Sand, unreclaimed salt marshes (saltings), and some reclaimed tracts, together with much bare mud; the National Trust Reserve comprises 3½ miles of the shingle spit from the Headland, and a strip of saltings abutting on the reclaimed marshes between Blakeney and Cley. It is remarkable that twenty-five small lateral shingle banks extend from the lee side of the main spit, and some of these known as 'Marams' are considered by Dr. Salisbury to possibly indicate the former extent of sand dunes, although the Marram grass (*Psamma*) is not now conspicuous. The marshward flow of the shingle is arrested to some extent by *Suæda fruticosa* and other plants. The distribution of the plants is fully dealt with by Dr. Salisbury, and the subject generally is well illustrated by maps and photographic views.

XI.—BRIEF NOTICES.

1. THE PALEOLITHIC IMPLEMENTS OF KANSAS.—A work entitled *The Weathering of Aboriginal Stone Artifacts*.—No. 1: "A consideration of the Paleoliths of Kansas," by Mr. N. H. Winchell, has been issued by the Minnesota Historical Society (8vo, cloth, St. Paul, pp. 186, illustrated by twenty figures and nineteen half-tone plates, 1913). In this volume the author applies the term Paleolithic "to any people, and their artifacts, which antedated the Kansan Glacial epoch. Early Neolithic includes the time elapsed between the Kansan and the Wisconsin Glacial epochs, and Neolithic applies to people who have existed in Kansas since the Wisconsin". Paleolithic types of implements were, however, found to continue into Neolithic times. The characters and patination of various implements are described and illustrated by the text-figures and plates.

2. YORKSHIRE CHALK FOSSILS.—"The Chalk Fossils in the Hull Museum" form the subject of an article by Mr. George Sheppard (Trans. Hull Scient. and Field Nat. Club, iv, 1913). A useful list is given of the species, a few of which are figured in two plates.

3. North of England Bibliography.—Mr. Thomas Sheppard continues his helpful list of "Papers and Records relating to the Geology and Palæontology of the North of England", those for 1912, Yorkshire excepted, being printed in the *Naturalist* for July last. It is announced that the Yorkshire items will be included in a memorial volume to the late C. Fox Strangways, that will shortly be published by the Yorkshire Geological Society.

4. Coal-fields of India.—In vol. xli of the Memoirs of the Geological Survey of India (1913), the work on Coal-fields, by V. Ball, has been entirely revised and largely rewritten by Mr. R. R. Simpson. He gives a practical account of the subject, illustrated by views of colliery works and machinery, by maps of the Raniganj and Jharia Coal-fields, and a more general map of the Central Provinces and districts further east, including Burma. There is also a useful bibliography.

5. Water-supply Papers, Nos. 305, 307, and 308 (1913), continue the records of "Surface Water Supply of the United States", and give particulars relating to Hudson Bay and Upper Mississippi River, Lower Mississippi River Basin, and Western Gulf of Mexico. No. 318 (1913) is on the "Water Resources of Hawaii", by Messrs. W. F. Martin and C. H. Pierce. Maps are given of the drainage of Hawaii and associated islands; there are particulars of gaugings, rainfall, etc.; and views of scenery, irrigation-works, etc.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *November* 19, 1913.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

No papers were read, but in response to the invitation issued on November 5 eighteen or more exhibits were made of implements and reputed implements of Palæolithic and earlier age, and of flints showing various types of fracture.

The President, in opening the proceedings, said that the subject which had come before the Society for consideration was partly of anthropological interest, but fell also within the limits of geology. For the exhibits included specimens of flints from strata ranging in age so far back as the base of the Crag; and the determination of the age of the strata was clearly a matter for geological investigation.

The specimens exhibited included some for which evidence of human workmanship was claimed with much confidence, but without having obtained universal acceptance. There were also shown series of flints illustrating the manifold forms of fracture which are attributable to natural causes. A comparison of these with the reputedly artificial forms could not fail to be instructive.

A large number of flints, for which a human origin was claimed, had been found lying on the surface or embedded in the soil. These were chiefly of anthropological interest.

He considered that there were four lines of inquiry of primary importance—

1. Were the specimens obtained in situ in a geological formation ?
2. What was the geological age of the formation ?
3. Did the flints show indubitable proof of the handiwork of Man ?
4. Could such a sequence of types of implements be established in this country as to enable geologists to use implements as zone-fossils in the deposits of the Human Period ?

He then called upon each exhibitor to explain briefly the nature and object of his exhibit.

Mr. J. R. Moir exhibited specimens which included (1) implements from the base of the Suffolk Red Crag, comprising the well-known rostro-carinate type, borers, pointed forms, flakes, and scrapers; also some Cetacean bones which presented the appearance of having been fashioned by man; (2) flints flaked by the exhibitor, showing the various stages in the manufacture of a rostro-carinate implement; (3) four groups of implements from the Middle Glacial gravel underlying Boulder-clay; (4) a series of implements from the Boulder-clay; and (5) a series of implements of the Strépy type of Rutot from a Glacial gravel apparently later in age than the Boulder-clay.

Mr. F. N. Haward exhibited a series of bulbs of percussion and facetted flints, many with edges chipped on one or more sides, from Glacial gravels and the Cannon-shot Gravels of Norfolk. He pointed out that the large rounded flints from the Cannon-shot Gravels were a mass of cones of percussion, some exhibited being 1½ inches in diameter at the base, and of character similar to those produced artificially. From a Glacial gravel at Lenwade specimens were shown of tabular flints with chipped edges, and others which simulated closely the 'hollow scraper' and 'one-edge' work usually attributed to the hand of Man. From gravel at Tuddenham, full of split flints fresh from the Chalk, the edges of the flints exhibited were chipped almost entirely from one side: this chipping he attributed with confidence to natural agencies. For some years he had been working at certain types of chipped flints which some would consider artefacts, but of which he had grave doubts; and he had collected a large series from a pit at Eaton, near Norwich. This pit from its basement bed, which is 1 foot thick, yielded a remarkable series of flints with chipped secondary edges of various shapes. The basement bed consisted of three zones: The bottom zone was made up of Chalk in process of disintegration. The middle zone consisted entirely of much fractured chalk flints, many of which come away as a mass of splinters and contain bulbous flakes. The splitting of these flints was due to crushing in situ under great pressure, but the flakes show little or no secondary chipping. The top zone yielded all the chipped specimens which he exhibited, and he pointed out that they all came from one face of the pit, that they were collected in a horizontal distance of 12 feet, and were picked out by hand. The specimens are generally scratched all over, and many show remarkable selective work on one edge. A like series was also exhibited from a similar basement bed at Harford Bridges. They also occur at East Runton and in many other places where the basement bed is exposed. The so-called 'implements' generally occur where the basement bed is most crowded with flints.

In the speaker's opinion these chipped flints were simply the result of crushing by natural forces that acted during the cutting away of the Chalk, either by ice or snow before the gravels were deposited, or by lateral movement in the gravels under great vertical pressure.

Whenever a moving stone impinged on the sharp edge of a stationary flint, chips would be flaked off the flint along the lines of least resistance; but when the sharp edge of the flint is turned away from the impinging force no chipping will ensue. As regards the direct proof that these chipped flints were Nature's work, it was next to impossible to reproduce the conditions under which the natural chipping took place, and to make observations in a gravel buried under hundreds of tons of soil, ice, and snow. The speaker had, however, been able to exhibit naturally chipped flints which owed their character to the foundering of a mass of gravel in a pipe, the gravel breaking through a layer of flints in the Chalk.

Mr. S. Hazzledine Warren, in exhibiting the results of certain experiments upon flint, said that he wished to make it clear that these experiments were not conducted from the point of view of proving what Nature could do by the attempted simulation of natural causes, but from the point of view of investigating the properties of flint. What he was endeavouring to elucidate by experiment was the manner in which flint chipped when subjected to forces of measured strength applied in different directions. Many methods were being used, one of which was that of movement under pressure of a sled which could be loaded at will with different weights. This process resulted in the reproduction of the Kentish form of eolith, a load of 250 lb. being sufficient for the production of most of even the larger forms. It was, however, insufficient for the reproduction of the big chipping often present upon the sub-Crag flints.

In considering subsoil pressures, in a soil of medium weight (a clay-with-flints) a stone having a superficial area equal to a rectangle of 8 by 6¼ inches was under a pressure of 250 lb. at slightly less than 6 feet below the surface; at a depth of 50 feet the same stone would be under about nine times that pressure, while beneath 500 feet of ice it would be under forty times that pressure. It was important to remember that striated surfaces were associated with both the Kentish 'eoliths' and the sub-Crag flints, and these pointed to the conclusion that strong movements under pressure had actually operated upon the flints in question.

Although the speaker did not wish to postulate too close an analogy between experimental and natural conditions, yet if, broadly speaking, the chipping properties of flint discovered by experimental investigation could be relied upon as also applying under natural conditions, then such chipping as was seen in the flints in dispute might theoretically be expected to occur.

A small series of chipped flints obtained from the base of the Tertiary beds at Harefield was also exhibited. In this section the bulbous chips could be found in the facets of the parent blocks from which they had been forced away by the operation of subsoil pressure.

Mr. A. S. Kennard exhibited, on behalf of Mr. B. Harrison, a series of eoliths from the Chalk Plateau of West Kent. This type of worked flint was first described by the late Sir Joseph Prestwich and had formed the subject of a considerable literature. It is obvious that the palæoliths cannot be the earliest efforts of man, and, although some of the stratigraphical evidence of the plateau is conflicting, yet, on the whole, it would appear that they are older than the Palæolithic gravels. This is clearly seen at Swanscombe, where the 'eoliths' are certainly derivatives. In South Africa a similar sequence can be shown, and this is of the utmost importance. It was quite impossible to say definitely where the work of Nature ended and that of Man began. It was purely a personal matter, but the speaker was confident that many of these rudely chipped flints were human artefacts. As a group they differed from the sub-Crag flints and many other so-called 'eoliths'.

Colonel A. W. Jamieson exhibited a series of specimens that he had collected in the south-east of Hampshire, and he wished to draw attention to this district, for he thought that it deserved more consideration than it had yet received. The area is bounded on the north and west by the Meon, on the east by the Sussex border, and on the south is the undercliff of the Isle of Wight. This country is strewn with worked flints of all ages, especially so from the Chalk summit to the sea.

Worked flints were furnished by a series of gravels on the marine plain, summarized on the geological map as Plateau Gravel. The sections are good and constantly varying on account of the rapid destruction of the coast.

The bottom layer of these gravels, which rests on denuded Bracklesham Beds, consists of Arctic drift full of igneous erratics and crowded with flints of café-au-lait and ochre colour, together with subangular masses cut about in a manner similar to those exhibited by Professor Sollas. So-called 'eolithic' forms are abundant. Upwards early Palæolithic forms follow with the conventional Drift types, several of which were shown. On the top is the Brick-earth or Loess, crowded with worked flints which have the appearance of being Aurignacian. They include steep-sided side-scrapers and segmental tools. In this deposit the speaker had discovered a human skeleton, minus the skull, the bones of which are now undergoing examination by Professor Keith. Above the marine plain a point of interest is the conspicuous hill of Portsdown, which has yielded a vast number of flints, worked on one side, shorn off flat on the other, and bearing conspicuous cones and bulbs of percussion.

The high Chalk of the interior is in places patched with Clay-with-Flints which has withstood destruction, and is rich in fabricated flints, which, in the speaker's opinion, were chiefly Mousterian.

Implements were also shown from Catherington, Hixton, Windmill Hill, and Blendworth, the last-named locality being rich in segmental tools and half-finished work showing huge cones of percussion. The speaker urged the view that the Clay-with-Flints was a formation coeval with the history of Man.

Professor Sollas exhibited a series of specimens to illustrate the production of 'rostro-carinate' forms of flint by natural agencies.

One from the top of the Chalk at Swanscombe showed jointing in situ, and some from the beach under the Chalk cliffs of Alum Bay the effects of wave-driven pebbles; but the great majority were obtained by Mr. E. Heron-Allen from the beach of Selsey Bill, and it was to these that attention was especially directed. If they were all of human workmanship—Sir E. Ray Lankester's contention—there would be no difficulty in accounting for the characters which they possess in common, notably their abundant and bold flaking; but then the fact that some examples were bounded on one side by planes of Pleistocene age and on the other by planes of recent origin would remain unexplained. If, on the other hand, only certain specimens were selected as artefact—Mr. J. R. Moir's interpretation—then it became difficult to explain the flaking which they all possess in common; and the fact will still remain that 'rostro-carinate' forms may be produced by flaking of widely separate ages. Some of the flints showed recent chipping under circumstances which suggest that this had been produced by the blows of pebbles driven inland from the sea: that is, in one direction. Attention was also called to 'rostro-carinate' forms projecting from the side of a large boulder of flint.

The Rev. H. H. Winwood exhibited specimens of quartzite and flint implements from the Broom, Farnham, and Knowle gravel beds. His object was to show the gradation from the well-worked implements of undoubted human origin to the fractured specimens from the Brinkworth plateau gravels 400 feet above O.D., the so-called 'eoliths', the origin of which is so much disputed. A porcellanous or more probably altered chert implement from Somaliland and a flint specimen from the cave shelter at Le Moustier showed how universally this type prevailed. Especial attention was called to a broken flint found by himself in the Knowle gravel-pit at Savernake, which had a remarkable glaze over the surface, not only of the fractured but also of the old surface, the cause of which yet awaited explanation.

Mr. H. N. Ridley exhibited a series of stone implements from the eastern coast of the Malay Peninsula, found in river-gravel and in one case on a bed of alluvial tin-ore. Nothing further is known of the race which made these tools, and it is certain that it is long extinct. He also showed some modern Papuan weapons of stone, in order to illustrate the methods of fastening the stones to the handles, and some sandstone tanged adzes with shell ornaments and spindle-whorls from the lake-dwellings of Kampong Thom in Cambodia, also of unknown date.

Mr. O. A. Shrubsole exhibited a few specimens from the Reading district in order to show difference of age and variety of use. The eoliths were from the gravel of the Easthampstead plateau (300 to 400 feet O.D.). The palæoliths included hollowed scrapers (highly developed from the eolithic type), gimlets or drills, knives (sometimes with a tang for insertion in a handle), saws, choppers, pickaxes, and polishers. One of the last-named still bears a finger-print of ancient man. Heavy two-handed choppers also occurred, identical in form with a specimen shown from the base of the Red Crag. Two at least of the Crag specimens were good Palæolithic types. He showed in addition three specimens of bone (radius and rib of *Bos*) which had been cut very neatly by a flint instrument. Two flint implements were also exhibited which, by the difference of patina, indicated that they had been reworked at a much later date.

Mr. W. Dale exhibited a series of naturally formed or naturally fractured flints; these included an assortment of flakes caused by the bursting or expansion of the flint. One of these, on the base of an Echinoid, remains in situ, and can be taken out and replaced in the cavity. Some specimens illustrated the 'starch-fracture' arising from the partly crystalline nature of the flint and producing irregular prisms. From implementiferous gravels he exhibited a quantity of the fossil organisms known as *Coscinopora*. In the Chalk these are imperfectly pierced, but in the gravel the holes become enlarged, and Sir Charles Lyell and Mr. Worthington Smith thought that they might have been used as ornaments. The specimens shown were obtained from a gravel-digger, who was in the habit of placing them on strings. Flints which simulate Palæolithic implements in their form were also shown, and a collection of natural shapes somewhat resembling animal forms, one of them strikingly like a human head. The speaker would not have thought it worth while to show these last, but for the fact that the vagaries of the late Auberon Herbert had found another exponent, and the Journal of the British Archæological Association had this year published drawings of a number of these objects and advanced them to the dignity of artefacts.

Mr. N. F. Robarts wished to draw particular attention to some of the eoliths which he exhibited, found upon the plateau of the North Downs in Surrey, at 800 feet above O.D., near the crest of the escarpment. Of these some were rolled, and it was therefore evident that these must have been derived from the Chalk dome which formerly existed over the Weald.

Mr. G. W. Lamplugh showed a fragment of glaciated clay-stone of rectangular shape from the Boulder-clay of a Flintshire colliery shaft, as an example of the artificial aspect occasionally brought about by natural fracture. The shape of this example was remarkably close to that of a manufactured whetstone. The speaker observed that, where the cause of fracture was uncertain, it became of prime consequence to know the proportion that selected specimens bore to the total number examined: since, if the supply of naturally fractured stones be unlimited, exceptional types such as the specimen that he exhibited must occasionally be found.

Mr. W. H. Cook exhibited fifty examples of eoliths and thirty palæoliths collected from the northern flank of the Weald. As a result of his investigations the speaker questioned the pre-Palæolithic age of the eoliths of this area: for during the last six years he had found considerable numbers of palæoliths lying in conjunction with eoliths on the surface at levels ranging from 450 to 765 feet above O.D. The implements of both classes are in a precisely similar mineral condition, and the amount of abrasion is likewise common to both. A typical Kentish eolith is a deeply patinated nodule of flint with one or more of its edges chipped, such chipped edges being in general of a lighter ochreous patination than the other parts of the nodule. It was noteworthy that some of the deeply patinated palæoliths had a subsequent or rechipped edge with exactly similar characteristics in regard to patina and angle of chipping as the eoliths with which they were associated. It had been said that palæoliths did not occur beneath the humus, but the speaker had had excavations made at levels of 450 and 520 feet above O.D. At the lower level he had found numerous eoliths and a rolled Palæolithic flake at a depth of 4 ft. 6 in.; at a further depth of 2 feet he found unrolled unochreous eoliths. At the higher level he had detected a much rolled Palæolithic implement in conjunction with numerous eoliths. He considered, therefore, that the contemporaneity of eoliths and palæoliths was beyond doubt.

Mere crudity of the fabrication of an implement could not be regarded as an indication of pre-Palæolithic antiquity: for, if that were allowed, many rudely fashioned implements, found associated with the higher forms in the drifts of our river-valleys and on the surface with polished tools, would have to be regarded as of greater antiquity than the finished examples, whereas there was good evidence to the contrary. This claim to a pre-Palæolithic antiquity for implements of crude workmanship could not be upheld when with them were found Palæolithic implements of Chellean and Acheulian types, in precisely the same mineral condition and showing a like amount of abrasion.

Mr. Reginald A. Smith referred to the type series of flints from the excavations carried out in 1912 on behalf of the Geological Survey and the British Museum. The official account was about to be published by the Society of Antiquaries (*Archæologia*, vol. lxiv), and dealt with the 100 ft. terrace gravels at Milton Street, Swanscombe, long known as a most prolific site. The 35 ft. section of Pleistocene deposits contained three bands of gravel, separated by two bands of loam. The lowest gravel, resting on Thanet Sand, contained a large number of struck flakes, unrolled and without secondary chipping, but no implements in the ordinary sense of the term, though some chipped cylindrical nodules might be regarded as of Strépy type. The Chellean types occurred abundantly in the middle gravel, especially in its lower section, the industry higher in the same bed showing an approach to Acheulian forms; but though the latter had been found from time to time in the pit and in the vicinity, no results were obtained during the excavations. Subsequently Mr. Dewey had acquired a series of unrolled Acheulian implements, mostly twisted ovates, from a bed corresponding to the Upper Gravel, in an adjoining pit. Hence the whole series, generally known as the Drift, seemed to be represented in the 100 ft. terrace-gravels, as was also the case in the Somme Valley. This did not preclude the possibility of Drift forms occurring in gravels at higher or lower horizons; and recent discoveries on the North Downs and other sites in the South-East of England suggested that some of the beds mapped as Plateau Gravel were laid down or re-arranged in the period named after St. Acheul.

A discussion on the above-mentioned exhibits then followed.

2. *December* 3, 1913.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read—

1. "A Contribution to our Knowledge of the Geology of the Kent Coal-field." By Dr. E. A. Newell Arber, M.A., F.L.S., F.G.S.

In this paper an attempt is made to give a general and connected account of the Carboniferous rocks of Kent, based on the evidence of some nineteen borings or sinkings. The Mesozoic cover of this wholly concealed coal-field is ignored. It is shown that the proved area is 200 square miles (128,000 acres), partly lying beneath land, and partly beneath the North Sea, the Straits of Dover, and the English Channel. The general strike is about 30° south of east and north of west, and the dip of the Transition Coal-measures is 2° to 3° in the two localities where reliable evidence is alone available on this point.

The area, as a whole, is a syncline, limited on the north and south by Armorican folds, of which the northern has been now fairly accurately located. There is evidence also of a fold on the east; and it is maintained that the Kent Coal-field is not continuous with that of the Pas de Calais. There are reasons for believing that the western boundary is a great fault.

The chief surface feature of the Coal-measures is that of an inclined plane, sloping rapidly but regularly westwards and south-westwards from an elevated region near Ripple and Deal in the east.

The Lower Carboniferous rocks exceed 450 feet in thickness, and were denuded before the Coal-measures were deposited.

The Coal-measures consist of the Transition Series (1,700 to 2,000 feet thick), and the Middle Coal-measures (2,000 feet). No Lower Coal-measures or Millstone Grit occur. The measures are grey throughout, and no red rocks, Espley rocks, *Spirorbis*-limestones, nor igneous rocks occur.

The coals are well distributed, and are often of considerable thickness, although there is a frequent tendency to splitting and inconstancy. Steam and household coals predominate, but gas coals also occur.

The most productive portions of the measures are the higher part of the Transition and the lower part of the Middle Coal-measures.

2. "On the Fossil Floras of the Kent Coal-field." By Dr. E. A. Newell Arber, M.A., F.L.S., F.G.S.

The floras of ten further borings in Kent are here recorded, and the number of species known from the Kent Coal-field is raised to 96, as compared with 10 known in 1892 and 26 in 1909. A number of the more interesting records are described and figured, some of them being new to Britain or not previously found on the horizons in question.

As regards the horizons present in Kent, the plant-remains indicate that, in the area so far proved, only Middle or Transition Coal-measures, or both, occur.

3. *December* 17, 1913.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

"Supplementary Note on the Discovery of a Palæolithic Human Skull and Mandible at Piltdown (Sussex)." By Charles Dawson, F.S.A., F.G.S., and Arthur Smith Woodward, LL.D., F.R.S., Sec.G.S.

The gravel at Piltdown (Sussex) below the surface-soil is divided into three distinct beds:—

The first, or uppermost, contains subangular flints and 'eoliths', and one palæolith was discovered there in situ.

The second is a very dark bed, composed of ironstone and subangular flints. All the fossils so far found in the pit have been discovered in or traced to this bed, with the exception of the remains of deer. A cast of a Chalk fossil, *Echinocorys vulgaris*, from the zone of *Micraster cor-testudinarium*, occurred as a pebble.

The third bed was only recognized this year, and consists of reconstructed material from the underlying Wealden rock (Hastings Series). It is only about 8 inches thick, and contains very big flints (8 to 15 inches long), which have been little rolled, and are not striated. They are saturated with iron, and have undergone considerable chemical change. They differ very markedly in appearance from the smaller flints in the upper strata. No implements, 'eoliths,' nor fossil bones have been met with in this bed.

The floor of the gravel, where the remains of *Eoanthropus* were discovered, has been carefully exposed, and many irregularities and depressions have been found to exist. In some of these depressions small patches of the dark overlying bed remained, and new specimens were recovered. The method adopted in excavation is described.

The finds made this year are few but important, and include the nasal bones and a canine tooth of *Eoanthropus*, also a fragment of a molar of *Stegodon* and another of *Rhinoceros*, an incisor and broken ramus of Beaver (*Castor fiber*), a worked flint from the dark bed, and a Palæolithic implement from the debris in the pit. It will be noted that the remains are those of a land fauna only. The further occurrence of bedded flint-bearing gravels in the vicinity of the pit is noted.

The authors' former conclusions, as to the Pliocene forms having been derived, are maintained.

A further study of the cranium of *Eoanthropus* shows that the occipital and right parietal bones need slight readjustment in the reconstruction, but the result does not alter essentially any of the conclusions already published. The nasal bones, now described, are typically human, but relatively small and broad, resembling those of some of the existing Melanesian and African races. The right lower canine tooth may be regarded as belonging to the imperfect mandibular ramus already described. It is relatively large and stout, and, like the molar teeth, it has been much worn by mastication. The worn surface on the inner aspect extends down to the gum, and proves that the upper and lower canines completely interlocked, as in the apes. In shape the canine resembles the milk-canine of man and that of the apes more closely than it agrees with the permanent canine of any known ape. In accordance with a well-known palæontological law it therefore approaches the canine of the hypothetical Tertiary Anthropoids more nearly than any corresponding tooth hitherto found.

The rolled fragment of an upper molar of *Rhinoceros* is highly mineralized, and has the appearance of a derived fossil. It is specifically indeterminable, but seems to agree best with the teeth of *Rh. etruscus* or *Rh. mercki* (=*leptorhinus*, Owen).

II.—Mineralogical Society.

Anniversary Meeting, *November* 11.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

A. Hutchinson and A. M. MacGregor: A Crystalline Basic Copper Phosphate from Rhodesia. The mineral occurs at the Bwana M'Kubwa copper-mines as a crust of minute, brilliant, peacock-blue, orthorhombic crystals, associated with malachite. Axial ratios a : b : c = 0·394 : 1 : 1·01; forms 110, 011; hardness 4–5; specific gravity 4·1. Chemical composition, determined by an analysis of a small quantity of carefully-selected material, approximates to the formula $2\ Cu_3(PO_4)_2,\ 7\ Cu(OH)$; no water is lost on heating to 190°. Although it has much the same composition as some minerals included in the pseudomalachite family, it differs widely in its physical characters from dihydrite, the only well-defined crystalline member of the group, and is probably a new species.—Dr. G. T. Prior: On the Meteoric Stone of Wittekrantz, South Africa. The stone, which fell on December 9, 1880, at the farm Wittekrantz, Beaufort West, Cape Colony, is slightly chondritic, and consists of the usual aggregate of olivine and bronzite, with particles of nickeliferous iron and troilite. In chemical and mineral composition it is very similar to the Baroti meteorite previously described.—Dr. G. T. Prior: On the remarkable similarity in chemical and mineral composition of Chondritic Meteoric Stones. The close similarity presented by most chondritic meteoric stones, although generally recognized, has to some extent been obscured by the unduly elaborate classifications which have been devised. A review of the quantitative mineral composition of forty-two chondritic stones, and a critical examination of the published analyses of others, lead to the conclusion that almost all those at present known are, except for some variation in the amount of nickeliferous iron, practically identical in chemical and mineral composition, the identity extending even to the chemical composition of the individual constituents. They approximate to the type with the following percentage mineral composition: nickel-iron (Fe : Ni = 10) 9, troilite 6, olivine (Mg : Fe = 3) 44, bronzite (Mg : Fe = 4) 30, felspar 10, chromite, etc., 1.—Arthur Russell: Notes on the Minerals occurring in the neighbourhood of Meldon, near Okehampton, Devonshire. The principal species are datolite, in crystals sometimes $2\frac{1}{2}$ cm. in length, sea-green in colour and nearly transparent, polysynthetically developed, and showing a cleavage parallel to 001;

apophyllite in three types, square, tabular, and pyramidal; pyrrhotite in thin hexagonal plates; tourmaline in black, brown, green, blue, and pink crystals, sometimes zoned; garnet in colourless cubo-dodecahedra and trapezohedra, sometimes including wollastonite hairs; wollastonite abundantly in pure-white fibrous masses.—J. B. Scrivenor: On a Calcium-iron-garnet from China. It is interesting on account of its unusually easy solubility in hydrochloric acid without ignition.

III.—Zoological Society of London.

November 25, 1913.—Professor E. W. MacBride, M.A., D.Sc., F.R.S., Vice-President, in the Chair.

Mr. T. H. Withers, F.G.S., contributed a paper, communicated by Dr. W. T. Calman, F.Z.S., based upon a large series of Cirripede remains from the Cenomanian Chalk Marl in the neighbourhood of Cambridge. The greater number of the specimens are referred to two species of the family Pollicipedidæ, and add materially to our knowledge of the phylogeny of the pedunculated Cirripedes. Both forms are remarkable for their advanced form of scutum, in which the umbo is sub-central, and show that the transition of the scutal umbo from an apical to a sub-central position was acquired independently by unrelated forms in distinct lines of development.

OBITUARY.

SIR ROBERT STAWELL BALL, LL.D., F.R.S., F.R.A.S.

Born July 1, 1840. Died November 25, 1913.

Sir Robert Ball was born in Dublin and was the son of Dr. Robert Ball, an ardent naturalist and Director of the Museum in Trinity College. After graduating as University student in Mathematics in that college, Robert Ball (the younger) was appointed Astronomer to the 3rd Earl of Rosse at Parsonstown in King's County. He was elected a Fellow of the Royal Society in 1873, and eventually became Lowndean Professor of Astronomy and Geometry in the University of Cambridge and Director of the Cambridge Observatory. To geologists he was known chiefly as the author of a small volume on *The Cause of an Ice Age* (1891), a work reviewed by the Rev. Osmond Fisher (Geol. Mag., 1892, p. 231). He described it as containing "a very clear and agreeably written exposition of the commonly received Astronomical theory of Glacial periods", as adding "fresh force to Dr. Croll's hypothesis", but as "rather too triumphant" from the geologist's point of view. Since then Croll's hypothesis has been practically demolished by Mr. E. P. Culverwell in the pages of this Magazine (1895) and the Astronomical theory of the Ice Age has been abandoned. Sir Robert Ball was likewise author of a work entitled *The Earth's Beginning* (1901).

PROFESSOR IGINO COCCHI,

For. Corr. Geol. Soc. Lond.

BORN 1828. DIED 1913.

WE regret to record the death of the veteran Italian geologist, Professor Igino Cocchi, of the Museum of Natural History, Florence, Italy. Born at Terrarosia, in the Valdi Magra (province of Massa) in 1828, he at first devoted himself to literary studies, especially Latin literature, afterwards to chemistry, anatomy, and botany, and finally to mineralogy and geology, notably palæontology and stratigraphy. Having graduated at the University of Pisa, he completed his studies abroad, especially at Paris and London. Later on he gave to the town of Florence his collections, which formed the nucleus of an important palæontological collection.

Returned to Pisa, he was for some time assistant to MM. Savi and Meneghini; he collaborated with Cont. A. Spada and others in the reorganization of their collections; and finally was appointed Professor of Geology and Mineralogy at the R. Istituto di Studi Superiori in Florence.

He founded the Alpine Club of Florence, and in 1867, under the Minister of Agriculture (M. Cordova and afterwards M. Broglio), established the Reale Comitato Geologico.[1] He was not a prolific writer; only a dozen papers stand to his credit in the Royal Society Catalogue, and some twenty or so separate memoirs.

DR. ALFRED RUSSEL WALLACE,

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

BORN JANUARY 8, 1823. DIED NOVEMBER 7, 1913.

THE closing year (1913) has borne away another of the great naturalists of the nineteenth century, whose researches and writings have so profoundly influenced biological science, and opened up for us entirely new conceptions of life both past and present.

Alfred Russel Wallace was born at Usk, Monmouthshire, on January 8, 1823; his family was not Welsh but Scottish in origin. His father, a man of literary tastes, was a briefless barrister with a family of nine children, of whom Alfred was the youngest but one. The future naturalist left school at 14, and from that time set himself to read *Mungo Park*, *Robinson Crusoe*, *Gulliver's Travels*, and later Lyell's *Geology*, Darwin's *Journal of a Naturalist*, Humboldt's *Travels*, *The Vestiges of Creation*, etc. His parents intended he should become a land surveyor and architect, but Nature designed him for a traveller and naturalist, and Dame Nature as usual prevailed. He practised surveying for some time in the Midlands and in Wales. Later on he was drawing master at the Collegiate School, Leicester. Here he became acquainted with Henry Walter Bates, and this proved the turning-point in his career. Bates, like Wallace, was born to be a naturalist, and the two decided to go in company to the Tropics to study animal life and make collections. They sailed from London in 1848. Wallace spent the next four and a half years collecting birds in South America. Returning home in

[1] From Gubernati's *Dict. Internat. Ecrivans du Jour.*

1852 the ship took fire; all on board had a narrow escape, and the naturalist's collections were totally lost. Wallace published his *Travels on the Amazons and Rio Negro* and then set out for the Far East. From 1854 until 1862 he spent amid the Malay Islands, then practically but little known to naturalists. In eight years of wanderings and voyages, amid those "green islands of glittering seas", he gathered the material for his *Malay Archipelago*, his *Tropical Nature*, his *Island Life*, and his *Geographical Distribution of Animals*.

During an illness at Ternate in 1858 he spent his enforced idleness by thinking out the problem of natural selection, which had occupied his mind and he had written about unsatisfactorily three years earlier. Wallace knew Darwin, and sat down and wrote to his friend a letter suggesting his ideas as to "the survival of the fittest", not knowing that Darwin had, nearly twenty years before that date, come to the same conclusion as Wallace, and had been collecting data to prove his theory. After much discussion with Sir Charles Lyell and Sir Joseph Hooker, it was decided that Wallace's and Darwin's independent papers should be read simultaneously in 1858 before the Linnean Society. Looking Nature in the face for long years and in many lands, both had arrived at the same great induction, that all living beings are descended from previous living forms and that these have changed and advanced in fashion from the beginning, those surviving that were the fittest. The Linnean Society recognized the equal merit of the two naturalists and awarded a medal to each. But Darwin and his followers held the field, and Wallace with true nobility and self-denial acquiesced in giving precedence to his friend. Thereafter Darwin's *Origin of Species* became known and accepted world-wide, and Wallace himself joined in its praise. In after years Wallace retained a vigorous pen and wrote prolifically upon many and various subjects, both books and scientific papers.

The Royal Society in 1868 awarded Wallace the Royal Medal and in 1890 the Darwin Medal. In 1908 he received the Copley Medal. It would be impossible to give a full account of Wallace's literary labours. He lectured in America in 1886–7. Alfred Russel Wallace was never in affluent circumstances. In 1881 he received a Civil List pension of £200 a year in recognition of the amount and value of his scientific work, and in the King's list of Birthday Honours for 1908 the name of Alfred Russel Wallace was deservedly placed in the list of the 'Order of Merit'.

MISCELLANEOUS.

We learn from *Nature* (December 4) that Dr. W. T. Gordon has been appointed lecturer and head of the geological department at King's College, in succession to Dr. T. F. Sibly, appointed professor of geology at the University of South Wales, Cardiff. Dr. Gordon has been lecturer in palæontology and assistant in geology at the University of Edinburgh since 1910, and has made extensive researches in palæobotany and some investigations in stratigraphical geology.

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THE

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A. Gilligan photo.

Coal-measures with Haigh Moor Coal, Robin Hood Quarries, near Wakefield.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. I.

No. II.—FEBRUARY, 1914.

ORIGINAL ARTICLES.

I.—On 'Cleat' in Coal-seams.

By Percy F. Kendall, M.Sc., F.G.S.,
Professor of Geology in the University of Leeds.

(PLATE III.)

MY interest in cleat was first aroused by the study of the Geological Survey memoir on the coals of South Wales (1908), from which it became clear to me that the subject of the origin of anthracite was intimately bound up with that of cleat. The object of the present communication is, however, not directly connected with the anthracite question, upon which I hope to have something to say when researches upon which I am engaged with Mr. E. J. Edwards, M.Sc., of Cardiff, have reached a more advanced stage.

The 'cleat', or system of joints traversing coal-seams, has strangely escaped investigation by any British geologist during the past half-century. But for brief and often conflicting references to the phenomenon in textbooks, among which those in Professor J. Geikie's *Structural and Field Geology* and Dr. Walcot Gibson's *Geology of Coal Mining* must be signalized as the most valuable, and for more or less casual allusions to it in papers by mining engineers, it might well be imagined that all recollection of the existence of such a structure had died out. The word 'cleat', or any *alias* by which it might be indicated, finds no place in the Index to the first fifty volumes of the Q.J.G.S., nor does it appear in the "Geological Literature added to the Society's Library". A search through about thirty memoirs of the Geological Survey relating to coal-fields failed to yield a word upon the subject.[1] Yet two quotations from earlier sources will suffice to show that problems of surpassing interest are presented by the disposition of the cleat in some British coal-fields. Jukes in his *Manual of Geology* (1862), p. 212, says: "The large smooth vertical surfaces [in a block of coal] are known by the name of 'the face', 'the slyne', or 'the cleat' of the coal in different districts, the more interrupted set being sometimes spoken of as 'the end' of the coal. The 'face of the coal' is the most necessary thing to attend to in laying out the working galleries or gate-roads of a coal-mine, since it retains its parallelism over very large areas." In a footnote he adds: "*In inquiring of a collier in the Nottinghamshire coalfield in the year 1838 as to the direction of 'the slyne' (as the face is there called), I was informed that it faced 'two o'clock sun, like as it does all over the world, as ever I heered on', by which I understood that the sun*

[1] Since this was written I have learned that in the South Wales Coal-field cleat is known as 'slips': with this clue I found an allusion to 'slip-cleavage' in the memoir above mentioned. It stated that there was none in anthracite.

would shine directly upon it at two o'clock in the afternoon in an open work or that the planes ran about W.N.W. and E.S.E., and were persistent in their direction in all my informant's district at all events." He quotes John Phillips's Report on Cleavage and Foliation in Rocks, etc., in the B.A. Report for 1856, and I give the passage *in extenso*:—

"§ 11. *The Cleat in Coal.*

"In the northern coal districts of England, and in other tracts, there exists, besides the lamination parallel to the bounding surfaces of the beds, a series of approximate, often nearly vertical divisional surfaces, along which the coal admits of easy fissility. This structure is called cleat, and it is of the greatest importance in coal working, since parallel to it the headways are driven in the 'post and stall' workings of Northumberland and Durham, and parallel to it the 'banks' are wrought in the 'long wall' and 'bord and end' systems of Yorkshire and Derbyshire. Cleat is little affected by fractures or undulations of the strata. It has usually one persistent course across a large district,—the same direction often obtains in neighbouring districts, and even prevails over the whole of a great Carboniferous region. Thus in Northumberland and Durham the cleat runs most generally to the north-west (true); its 'strike' is in that direction. The most general strike of the beds is to N.N.E. The same direction of cleat is prevalent in Yorkshire and Derbyshire, and this whether the beds strike eastward, as near Leeds and Sheffield, or southward, as near Huddersfield and Chesterfield. The same direction prevails in Lancashire."

In reading this pregnant passage one scarcely knows which feeling is uppermost—admiration for the marvellous industry and insight of Phillips, or astonishment that his generalization attracted so little of the attention of either his contemporaries or successors. So far as the Yorkshire Coal-field is concerned, his statement of fact is endorsed by all mining engineers with whom I have spoken, and I shall add some corroboration of my own.

The particular aspect of the subject to which I wish now to apply myself is the absolute independence of the cleat in coal-seams, not only to the lie of the rocks, but also to the jointing of the measures in immediate association with them. This relation is not explicitly indicated by Phillips, though it is perhaps implied by his statement that the direction of cleat maintains its constancy despite diametric changes of dip.

I will first substantiate the constancy of cleat by a few examples taken at random. All the bearings are *magnetic*.

Southowram, near Halifax, cleat . . .		N. 17° W.
,, ,, joints in roof	N. 63° W.	
,, ,, ,,	N. 39° E.	
Robin Hood Quarry, near Wakefield, cleat . .		N. 43° W.
Wheldale and Fryston, cleat		N. 22° W.
Allerton Bywater, cleat		N. 25° W.
Whitwood, cleat		N. 28° W.

The total variation of direction in these readings is 26°, or taking N. 30° W. as the direction most commonly observed in this coal-field the deviation is 13° to the west and 13° to the east.

The Southowram set of readings (one of several in the same colliery) is interesting, as showing that actually the jointing in the very roof of the seam is as divergent from the cleat as it is possible to be. A better case is, however, afforded by Robin Hood Quarry, midway betwixt Leeds and Wakefield. At this place a great pit has been excavated in the Middle Coal-measures for the extraction of shale for brick-making, and, as it is on the site of an old shallow coal-mine, not only was the shaft opened out, but many of the old roads in the famous Haigh Moor Seam, with their primitive oaken timbering, are now laid open to the day. The seam itself, roughly 3 ft. 6 in. in thickness, has been bared over a considerable area, and the unusual experience is afforded of studying one of the principal and quite the most interesting seams in this coal-field in open sections and plan. The surface of the seam shows very perfectly the direction of the cleat, and in the accompanying Plate III, from a photograph by Mr. A. Gilligan, the disposition of this structure and its relation to the dip of the seam and to the jointing of the measures are shown in a very instructive and convincing manner. The top 'lift' of the seam has been removed over a space in the foreground, and the recent rains have formed a pool of water, the general direction of the margin of which defines the strike; the rail placed perpendicularly to this gives the dip. The further side of the pool is a hewn edge of the coal, bearing no specific relation to the structure.

The coal-seam shows the two sets of joints known to the Yorkshire miner as the 'bord' and 'end'. There appear to be differences between local usages in the application of these terms, but a clear account of the custom in Yorkshire, as well as of the way in which the cleat affects the laying out of a colliery, will be found in a paper by Sir William E. Garforth.[1]

The 'bord' in this seam is formed by a very strongly marked and persistent system of joints, in the picture seen running along the right-hand margin of the pool and almost directly away from the observer. The faces are very smooth and lustrous, and are perpendicular to the bedding; they are in general parallelism, with very little convergence. In the most superficial layer of the seam the intervals are very small, not more than three-quarters of an inch. In the next layer the unjointed intervals are 2 inches in breadth, and in the massive seam below they are still larger. It may be said in general terms that the interval is roughly proportional to the thickness.

The 'end' is much less regular, and the direction varies from one pair of 'bord' joints to the next, so that the seam breaks with a ragged 'end'. These differences determine in a large number of cases the mode of laying out of a colliery: in the present instance the roads are bounded by 'bord' faces.

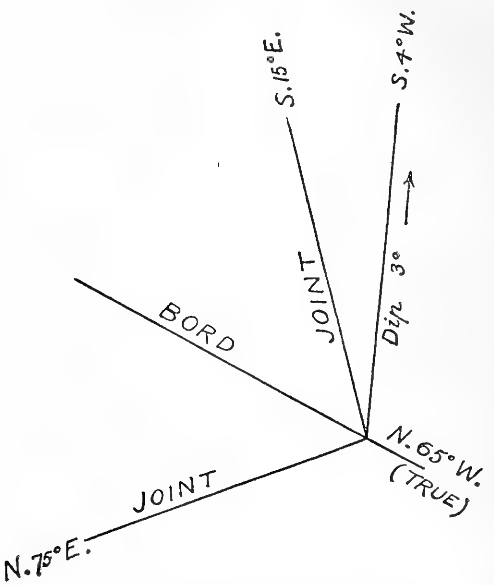
The surface of the seam is marked in some places by the imprint of large trees, and I observed one stigmarian impression. The imprints that I noticed were laid out about E. 10° N.

The beds resting immediately upon the seam are very argillaceous shales with many ironstone nodules with plant-remains, and they are

[1] Trans. Manchester Geol. and Min. Soc., vol. xxviii, p. 203, 1903.

followed by more shales with a couple of small coal-seams, but near the top of the picture can be seen the rectangular salients and re-entrants of a boldly jointed bed of hard sandstone. While the shales are shattered by irregular joints in all directions and in various azimuths, and therefore are valueless for comparison with the cleat, the sandstones afford trustworthy data. The photograph shows quite clearly that the prolongation of the cleat would almost exactly bisect these joints (see Figure). The case is quite typical of the unrelated disposition of the cleat to the jointing of the measures.

I refrain for the present from entering into any discussion of the cause of the cleat, but there is one question that seems to admit of an answer or at least a suggestion even at this early stage of the investigation, and I venture to deal with it now in the hope that I may elicit from some reader with a knowledge of lignite beds abroad information of which I am much in need.



The question I refer to is—Why does the jointing in the coal take a course absolutely unrelated to that of the enclosing measures? The first proposition I would advance is the obvious one that the two sets were produced by forces operating in different directions and at different times. The cleat would, I imagine, be produced first—otherwise it is difficult to understand why a fragile substance like coal should have escaped shattering by the force that jointed the other rocks, whereas if it had already acquired a cleat it might yield to later strains or stresses without the production of a fresh system of fractures.

Pursuing this inquiry further, we should ask to what property coal, or the peaty mass out of which the coal was later formed, owed its facility for early jointing. I adopt the following as a working hypothesis to guide me in further researches.

When our Coal-measures were first laid down they would consist of a series of incoherent sands and muds, and this uncompacted condition may have persisted for a very long period, so long as pressures were not excessive and no cementation took place; even surviving considerable tectonic disturbances, if we may judge by the condition of the Bovey Tracey Beds. The peats, however, would be subject to changes dependent upon processes entirely innate: the gradual loss of volatile constituents or at least the resolution of the carbon compounds into new groupings and the conversion of the mother-substance of the coal into lignite. This has happened, as Principal Clayden informs me, to the logs and trunks in the Bovey Tracey deposits, and I have observed the same thing in the coaly lenticles at Alum Bay. Professor J. J. Stevenson, in the latest of his brilliant and closely reasoned memoirs on the formation of coal-beds,[1] cites two instances of Quaternary peats passing into lignite.

In this condition the coal substance would be brittle and liable to joint. Now, let a deforming stress or strain be applied, or perhaps a wave or tremor sweep the country, and the sheet of brittle material would be shattered, while the unconsolidated sands and clays would of course be unaffected.

The idea that the initiation of joints, as it were the pulling of the trigger, is due to seismic tremors is urged by W. O. Crosby, and at a recent meeting of the Yorkshire Geological Society Mr. Harker remarked that the regularity of the joints in sedimentary rocks favoured the view that they were due to some kind of wave action. In no sedimentary rocks is there greater regularity than in coal.

I have no desire to press this or any other hypothesis, but I would remark that, though evidence is not lacking of considerable tectonic movements having taken place during the deposition of the Coal-measures adjacent to the Pennine area, it seems to me impossible to connect them with this widespread phenomenon that cuts, at all angles, the lines of structure of the country.

In conclusion, may I beg for information from those readers of the Geological Magazine who have opportunities for observing lignite beds occurring in uncompacted sediments regarding the development of cleat.

II.—The Geology of South Georgia.[2]

1. Notes on the Geology of South Georgia.

By D. Ferguson, Mem. Inst. M.E., F.R.G.S.

The island of South Georgia is nine hundred miles S. 80° E. from the Falkland Islands. The coastline of the island is rock-bound and more or less precipitous, and there is neither open beach nor

[1] Proc. Amer. Phil. Soc., lii, 208c, p. 33.

[2] A more detailed account of the geology of South Georgia, and of its rocks and fossils, will appear in one of the volumes on the results of the Scotia Expedition, which are now being published by Dr. W. S. Bruce.

detrital flat on its outward margin. A narrow valley, a morainic flat, inside Cumberland Bay, runs up 4 miles to a glacier, and there are other patches of morainic material, marking the recession of the glaciers. Leith Harbour is one of these, and Elsie and Adventure harbours, originally enlarged by the ice into one channel, have been separated into two safe anchorages by morainic material.

The Allardyce range of mountains forms the longitudinal axis of the island, running approximately north-west and south-east. The highest crests of the range, Mount Paget, the Sugar Loaf, and the Nordenskjöld Peak, are near the centre of the island. The outer coast escarpments are succeeded inland by rocky heights, having ice in every hollow. The central range, except on steep rock escarpments and splintery crests, is covered with permanent ice-fields and snow.

The greatest length of the island is about 110 miles, and its greatest breadth across Cumberland Bay and Mount Paget is just over 29 miles. The height of Mount Paget is given as 6,000 feet above sea-level on the charts of the island, but it was found to be 8,383 feet, from a base-line which was in part measured, and for the larger part the mean of a series of speed runs by a whaling steamer in Cumberland Bay, as no other method was available at the time. There can be little doubt, however, that Mount Paget is much higher than 6,000 feet, which has probably been stated as an approximation in the absence of accurate determination instrumentally.

Geological Literature.—Captain Cook called the island Georgia in honour of King George III. He sailed down the north-east coast from Willis Island to Cooper Island at the south-east extremity. We owe to this explorer the names of many of the promontories and bays, first discovered by him and now familiar to navigators in the South Atlantic. Possession Bay was named by Captain Cook on account of his landing there and taking possession of the island in the name of King George III. He refers to rocky islets and rocky hillocks, but does not give any details of geological structure. He makes the interesting statement that he did not find a stream of fresh water on the whole coast, and that only along the escarpments of the north-eastern coast is there warmth enough to melt the snow. In recent years the whaling industry has obtained ample supplies of the purest fresh water, flowing from the base of the glaciers on the north-east coast.

Captain James Weddell [1] also visited the island, and described it as so deeply indented that boats are frequently transported overland from one coast to the other.

Dr. Otto Nordenskjöld [2] states that the general features of the South Georgian landscape are similar to those of Spitzbergen. Mountains and fiords follow each other in the same way, but the fells of South Georgia rise from the coast, in most places, precipitously to almost inaccessible ridges. He describes this island, situated in lat. 54° S., as having glaciers as large as those of Spitzbergen in lat 80° N. He found traces everywhere in Mai Viken, Cumberland

[1] J. Weddell, *A Voyage towards the South Pole*, pp. 50–4.

[2] O. Nordenskjöld, *Antarctica*, p. 340.

Bay, of a former ice-covering, with morainic gravel and beautifully scored glacier stones, which proved that an immense mass of ice had once filled the entire valley. During a visit he paid in 1902 to Moraine Fiord in Cumberland Bay, he discovered the first fossil found in South Georgia embedded in an enormous block of stone.

K. Fricker [1] in his account of the island adopts the view that it is connected with the Cordilleras of South America and with the Sandwich Islands. He considers the outline, the narrow extended form, and the deep fiords prove the fact that in South Georgia we have a portion of a broken and submerged mountain chain. He quotes the geological features described by Hans Thürach, the geologist of the German Scientific Expedition of 1882. Near Royal Bay the rocks are clay-slates alternating with phyllite-gneiss, upon which follows clay-slate alternating with quartz-slate, and he says that huge banks of shale or diabase-tuff and sandstone occur near the Weddell glacier.

Dr. Fritz Heim,[2] geologist to the German Antarctic Expedition (1911) commanded by Lieutenant Filchner, states that the rocks at Royal Bay are chiefly phyllite, schists, and tuffs (?) of unknown age; and that the rocks have a north-west and south-east strike and southerly dip. According to his observations, the entire north coast, with the exception of Royal Bay and part of Cumberland Bay, appears to be built up of interstratified dark-grey to bluish-grey schists and greenish tuffs. The rocks of Royal Bay are of different appearance from all seen on the northern coast, and also from those in the inlets east of Royal Bay. He considers that South Georgia is a folded mountain chain, and that the general strike of the fold probably coincides with the strike of the island. Volcanic rocks were discovered from Novosilski Bay round to Drygalski Fiord on the south-eastern end of the island. In Larsen Harbour pebbles of crystalline rock of dioritic habit were found, and at Glosarczyk Fiord numerous blocks of acid rock of granitic type occurred everywhere in the moraines. He gives a qualified support to the view that South Georgia is allied to the Patagonian Cordilleras.

Rock Series exposed.—Unlike most small islands in the Atlantic, South Georgia is mainly a mass of sedimentary rocks. Its coastline for the greater part is formed of stratified rocks, generally indurated, and in places somewhat altered by pressure-metamorphism.

With the exception of two older but attenuated exposures of sedimentary rocks in Cumberland Bay and Cape George Harbour, the stratified rocks belong to one great series, which can be conveniently divided into three divisions, upper, middle, and lower. The largest and most impressive exposures of the series is in Cumberland Bay, but it stretches from Royal Bay to Cape North. Only a patch of the upper division of the series is seen near New Fortune Bay, and west of Cape North it comes in again, but the middle and lower divisions are well exposed from Royal Bay to Cape North.

[1] K. Fricker, *The Antarctic Regions*, 1900.

[2] F. Heim, "Geologische Beobachtungen über Süd-Georgien. Geologie der Deutschen Antarktischen Expedition": Zeit. Ges. Erdk. Berlin, 1912, No. 6.

The three divisions may be collectively called the Cumberland Bay Series, and divided into upper, middle, and lower divisions. The older rocks exposed in Cumberland Bay and Cape George Harbour, and separated from the Cumberland Bay Series by a well-defined unconformability, we have named the Cape George Harbour Series.

Cumberland Bay Series.—The upper, middle, and lower divisions of this series include all the stratified rocks of Royal Bay, New Fortune Bay, part of Cape George Harbour, and much the largest part of Cumberland Bay, the whole of Stromness Bay, Possession Bay, and on to the north-western extremity of the island at Bird Island. It also includes the stratified rocks from Bird Island and Cape Weddell along the south-west coast to Annenkov Island and Novosilski Bay.

The Upper Division of the Cumberland Bay Series.—The upper beds of the upper division have a creamy-white colour, which easily differentiates them from the middle and lower divisions of the series. These are succeeded by blue and purplish-coloured shales, which continue down to the upper beds of the middle division, which are whitish, and gradually change to a characteristic reddish-brown colour.

The rocks of this division when freshly fractured are of a grey colour, and but little different in texture or composition from those of the reddish-brown middle division underlying them. They are crystal-tuffs, grey grits, fine-grained greywacke, and slaty shales. They are in some cases coarser than the rocks of the two lower divisions, and the dark or black shales, strongly evident in the lower division and frequently seen in the middle division of the series, are only meagrely, if at all, present in the upper division.

The total thickness of the upper division can only be estimated provisionally at 1,500 feet. There are no higher horizons seen on the island, and consequently it is a denuded upper surface of the upper division that is exposed.

The upper division is well developed on Bird Island on the north-western extremity of the coast, and at Cape Weddell and Adventure Bay. It extends pretty generally as a fringe along the southern coast, including Cape Demidov and Cape Nunez, and on to Novosilski Bay. Annenkov Island is mainly formed of it, and so also is Cooper Island, off the south-eastern coast.

The Middle Division of the Cumberland Bay Series.—The middle division is easily distinguished by the reddish-brown colour of the rock exposures composing it. The colour is superficial, as the rocks are generally of a grey colour when freshly fractured.

The rocks of the middle division are more or less indurated, due to folding movements. They are highly siliceous, and while some of them are fine-grained others are gritty. There are still coarser sediments, which may be regarded as fine conglomerates, with very small rounded pebbles. Interbedded with them are black shales, not of great thickness in any one bed. The crystal-tuffs also occur in some quantity.

The thickness of the middle division cannot be less than 3,000 feet, and may be much greater.

The middle division of the Cumberland Bay Series is extensively developed along the north-east coast of the island. It extends more or less continuously from Cape North to Cape Charlotte on the southern shore of Royal Bay, and extends south-east to the isolated rocks north of Cooper Island, which have been named after Lieutenant Filchner. It forms the crests of the Allardyce Range, and occupies the higher ground of all the bays and fiords from Cape North to Cape Charlotte. It gives the characteristic reddish-brown colour to the rocks along the north-eastern coast. It extends south-east of Cape Charlotte, and west of Cape North for some distance, gradually disappearing under the rocks of the upper division at Bird Island and Cooper Island. It forms the crests of Mount Paget, the Sugar Loaf, and the Nordenskjöld Peak, 8,383, 7,779, and 7,760 feet respectively above sea-level. The bedding of the rocks of the middle division is extremely well marked, and several of the wall-like escarpments on the shoulders of Mount Paget resemble the rock escarpments of Table Mountain at Cape Town.

The middle division must extend along the south-eastern coast of the island for a great part of its length along the higher ground, eventually disappearing near sea-level under the upper division.

The Lower Division of the Cumberland Bay Series.—The lower division is formed of dark or black gritty shales and greywackes. Dark or black fissile shales reach a considerable thickness, and collectively they are the predominant body in the division. They alternate with gritty and fine-grained arenaceous shales, and coarser gritty shales which may be regarded as greywacke, with a few crystal-tuffs. There is much felspathic material in rounded and angular grains in the greywacke, and their prevailing grey colour, contrasted with the black of the shales, gives a distinguishing shade to the division.

The total thickness of the division is not disclosed in any of the exposures seen, as they invariably descend below sea-level, and the full thickness is not seen, but so far as can be judged, the lower beds seen amount to about 1,200 feet.

The lower division of the Cumberland Bay Series occupies a fringe of the lower ground near sea-level from Royal Bay to Port Gladstone, Possession Bay. In Royal Bay, Cumberland Bay, Stromness Bay, and Possession Bay, it can be easily seen coming in below the middle division and underlying it conformably. Its base has not been exposed; the lowest exposures are seen in Royal Bay, where it is permeated with crystalline quartz in a network of veinlets in very fissile black shales. Subsequent to the disposition of secondary quartz, earth-movements have crumpled the beds.

In the black shales of this division in Moraine Fiord, Cumberland Bay, there is an intrusion of diabase. It was probably intruded during the deposition of the rocks of the middle division, and was contemporaneous with volcanic eruptions which took place when the lower beds of that division were laid down. There is much volcanic debris and tufaceous material in the beds of the middle division, and their red, rusty-brown colour is very probably due to the decomposition of trachytic lavas.

Cape George Harbour Series.—The rocks of this series are only seen in Cape George Harbour and in Cumberland Bay. They are separated in both places by a well-marked unconformity from the rocks overlying them. They were probably folded before the denudation which shaped the old land surface had begun to operate.

At Cape George Harbour they are overlain unconformably by the middle division of the Cumberland Bay Series. They descend below sea-level in Cape George Harbour and in Cumberland Bay, and do not rise more than 500 feet above it. In the glacier glen to the north-west off Cape George Harbour they are over 500 feet thick.

Rock Series exposed: Distribution.—The total thickness of the various series of stratified rocks is only provisionally estimated. They are not likely to be less than the estimate given here, but may on further investigation exceed it considerably, especially the middle series. Our present estimate is—

	feet	
Upper Division of Rocks	=1,500	Cumberland Bay Series.
Middle ,, ,,	=3,000	
Lower ,, ,,	=1,200	
Unconformability.		
Greenish-grey siliceous slates	= 500	Cape George Harbour Series.
Total thickness exposed	6,200	

There is such a marked difference between the greenish-grey siliceous slates and the three divisions of rocks above shown, that the unconformability which separates two geological periods probably indicates a considerable break in time.

Tectonic Geology.—The character of the rocks of the South Orkney Islands is strikingly similar to that of the three series which form the main mass of South Georgia. During the examination of South Georgia the writer obtained, through the courtesy of the Manager of the Falkland Whaling Company, which was operating in the South Orkneys, ten samples of the rocks of Washington Strait, Coronation Island. They are very similar to those of South Georgia, and the similarity was noted by Dr. Harvie Pirie, who saw them in the Geological Department, Glasgow University. Dr. Harvie Pirie was the geologist to the *Scotia* Antarctic Expedition of Dr. Bruce, and during it studied the geology of the South Orkneys.

South Georgia is a ridge mainly of stratified rocks, with its longitudinal axis identical with the general strike of the rocks. It has parallel faults on either slope of the ridge, letting down the rocks to the north-east and the south-west. The evidence of faulting is proved by the middle division of the Cumberland Bay Series occupying the crest of Mount Paget with a slight south-westerly dip, while the upper division forms the coastline at sea-level on the southern side of the island, and is seen in a few straggling beds on the northern coast near New Fortune Bay. The rocks, moreover, have been greatly crumpled and contorted. The axis of the present Allardyce Range, the central framework of South Georgia, is parallel to the general strike of the sedimentary rocks, of which it is mainly formed.

Along the north-eastern coast of South Georgia there has been in places considerable crumpling and contortion of the rocks, principally of the middle division of the Cumberland Bay Series. King Edward's Cove, Cumberland Bay, Leith Harbour, Stromness Bay, and Possession Bay afford good evidence of the folding and crumpling of the rocks. The direction of thrust is from the north-east.

Professor J. W. Gregory has kindly examined the fossils brought home by the writer from South Georgia, and Mr. G. W. Tyrrell has kindly undertaken the description of the rocks. The fossils were all found, with one exception, on the beach where Leith Harbour turns round into Nansen Harbour. The one solitary exception was found on the beach at King Edward's Point, Cumberland Bay, and was apparently a fucoid, similar to those found at Leith Harbour. The whole of the fossils were obtained from the lower division of the Cumberland Bay Series. That specimens may be found in the same division in other parts of the island is highly probable. Leith Harbour was well searched because it was near the writer's head-quarters and easily accessible.

The finding of an undoubted fossil in the middle division of the Cumberland Bay Series in Prince Olaf's Harbour (Port Gladstone), Possession Bay, by the German Antarctic Expedition, is very important, and will no doubt be described by Dr. Heim at an early date. The writer was privileged to see the specimen, which was very kindly sent over to Glasgow from Heidelberg at the request of Professor Gregory.

In conclusion, the writer would like to put on record the generosity of Messrs. Chr. Salvesen & Co., the well-known shipowners of Leith, and of Mr. Theodore E. Salvesen, the member of the firm who specially directs their extensive whaling industry in South Georgia, South Shetlands, and the Falkland Islands. Messrs. Chr. Salvesen and Co. are the lessees of the minerals and mining rights on all the British islands in the South Atlantic outside the Falkland Islands. They have not, however, confined themselves to their own special interests, but have assisted and encouraged the elucidation of the interesting geological problems presented in that outlying portion of the empire. The rock and fossil specimens brought home from South Georgia have been presented by Messrs. Salvesen to the Geological Department, Glasgow University, and the Scottish Oceanographical Laboratory, Edinburgh.

2. Preliminary Note on the Rocks of South Georgia.

By G. W. Tyrrell, A.R.C.S., F.G.S.

Cumberland Bay Series: *Upper Division.*—This consists largely of hard, coarse, compacted crystal tuffs, dark-grey or black in hand-specimens, and resembling coarse greywackes. In thin section they contain fragments of trachytic lavas, and detached crystals of orthoclase and oligoclase in a paste of minutely crystalline material mixed with much indeterminate matter. Iron-ores and ferro-magnesian minerals are rare. In some of the rocks andesitic and latitic fragments are dominant, and occasional fragments of yellowish glass enclosing euhedral orthoclase are seen. Many of the rocks have suffered some degree of scapolitization. The tuffs pass into siliceous greywackes still with some recognizable volcanic material, and are interbedded with fine banded mudstones which appear to represent volcanic muds. Radiolaria have been recognized in these rocks as well as in the tuffs. The mudstones occasionally become somewhat laminated and pass into black shales. An imperfect cleavage traverses many of these rocks at a high angle to the bedding. These tuffs doubtless represent the interbedded 'diabas-schalstein' of Thürach.[1]

The *Middle Division* of the Cumberland Bay Series consists mainly of cleaved mudstones and siliceous shales or fine-grained grits, with a few bands of compact dark limestone, and one or two crystal tuffs, similar to those of the Upper Division. In thin section many of the grits are highly sheared, and a lamination has been set up parallel to the plane of shearing. The laminæ are frequently streaked with carbonaceous material and wind around uncrushed 'augen' of quartz. The more shaly bands are finely puckered and folded, and are traversed by quartz veins. Some of them contain a development of secondary mica. Rocks intermediate between shale and grit—siliceous slate or argillaceous grit—are common, and are frequently banded with alternations of more sandy and more shaly material. Most of these rocks are dark in colour and are distinctly cleaved. Some of the mudstones, however, are very hard and cherty, and almost devoid of cleavage-planes. The limestones are generally well cleaved. Only one shows traces of organic structures. Others contain a quantity of volcanic ash, or a considerable development of angular quartz chips, and are to be regarded as calcareous tuffs and grits.

The *Lower Division* of the Cumberland Bay Series consists of very similar types of rocks to the above, but exhibiting a higher grade of metamorphism. The mudstones are here transformed to black graphitic slates, which pass into phyllites by an increasing development of secondary mica on the cleavage-planes. Associated with these are highly sheared argillaceous grits, showing good augen texture in thin section. This association is probably the phyllit and phyllit-gneiss of Thürach. Less cleaved and altered mudstones are to be correlated with his thonschiefer. The slates and grits frequently occur in thin alternating bands, which show fine folding in the quartzose and extraordinary strain-slip and puckering in the argillaceous layers. Crystal tuffs, similar to those in the Upper and Middle Divisions, are also to be found amongst the rocks assigned to this division, especially at Port Gladstone, Cumberland Bay. One of these contains Radiolaria. A sheared limestone from Moraine Fiord is included in the collection.

Cape George Series.—Only four specimens of this series occur in the collection. They consist of grey, phyllitic, siliceous slate and black slate, much crushed and veined by quartz, otherwise not very different from the lower part of the Cumberland Bay Series.

[1] H. Thürach, "Geognostische Beschreibung der Insel Süd-Georgien": Internat. Polarforschung, 1882–3. Die deut. Exped., vol. ii, No. 7, p. 116, 1890.

IGNEOUS ROCKS.—Apart from the crystal tuffs described above, only two specimens of igneous rocks are found in the collection. One is a whitish, veined, altered rock, intrusive in the black shales of the Lower Division of the Cumberland Bay Series. This appears to be a coarse diabase or ophitic gabbro. In thin section it shows large plates of comparatively fresh colourless augite, penetrated by laths of decomposed felspar. There is also highly altered interstitial felspathic material with leucoxenic patches representing iron-ores. The other specimen was obtained from the moraine at the head of Moraine Fiord. This is a quartz-monzonite-porphyry with phenocrysts of oligoclase-andesine, orthoclase, and hornblende in a microcrystalline quartzo-felspathic ground-mass.

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3. THE GEOLOGICAL RELATIONS OF SOUTH GEORGIA.

By J. W. GREGORY, D.Sc., F.R.S.

THE special interest of the island of South Georgia depends on the evidence it promises as to the geological history of that part of the Southern Ocean which lies south of the South Atlantic. According to the well-known views of Professor Suess, South Georgia is on a continuation of the mountain line of the Andes, which at the southern end of South America bends eastward along the northern margin of Drake's Sea and continues 30° to the east, where it turns southward; it completes a great horseshoe-shaped course by passing through South Georgia and returning westward through the South Orkneys to Grahamland.

The geology of South Georgia has remained but little known. The first important contribution was made by Thürach, a member of the German South Polar astronomical expedition of 1882–3. According to Thürach[1] the island consists of a series of metamorphic rocks ranging from granular gneiss to clay-slate, and of beds of diabase tuff. The granular gneiss was only found as a shore pebble, but the inference that it came from the island was natural. The main rock series collected by Thürach includes a 'phyllite-gneiss' containing tourmaline, apatite, iron-ores, and andalusite; the prevalent rocks are phyllites and clay-slates, with which are interbedded some granular limestones, calc-phyllites, and quartzites. According to Thürach, there is a complete passage from the phyllitic gneiss to the slates,[2] and his illustrations[3] show that the rocks are very crushed and crumpled. The abundant diabase and tuffs recorded by Thürach suggested that South Georgia had been an active volcanic centre, and Gunnar Andersson's identification of some of the igneous rocks as porphyrite (i.e. altered andesite) was in favour of South Georgia having been part of the Andean line. Thürach obtained no evidence as to the age of the rocks, and the first fossil from the island was collected by the Swedish expedition. Dr. Otto

[1] H. Thürach, "Geognostische Beschreibung der Insel Süd-Georgien": Internat. Polarforschung, 1882–3. Die deut. Exped., vol. ii, No. 7, pp. 109–66, 1890.

[2] Ibid., p. 131. [3] Ibid., pp. 154, 157, 158.

Nordenskjöld kindly tells me that this fossil has been identified as a *Posidonomya* and as probably Mesozoic. This conclusion recalls Darwin's view of the Cretaceous age of the similar clay-slates of Tierra del Fuego.

The *Posidonomya* was found in phyllitic rocks in Cumberland Bay, and further to the west, on the same part of the northern coast, Dr. König, of the German Antarctic Expedition under Lieutenant Filchner, found a fossil which Dr. Fritz Heim, the geologist of the expedition, identified as part of an Ammonite. The fossil is badly preserved; it has been submitted by Professor Salomon to Professor Pompeckj, who says that it *may be* an *Acanthoceras* and may be 'Kreide'. Professor Salomon has kindly given us the opportunities to see this specimen in Glasgow, and its matrix agrees closely with the rocks collected from the same locality by Mr. Ferguson; they come from the middle part of the Cumberland Bay Series and are largely composed of volcanic debris.

The preliminary paper in which Dr. Heim[1] has announced the discovery of this fossil shows that South Georgia contains a varied series of rocks; for in addition to the slates and tuffs described by Thürach, Dr. Heim records, from widely separated localities, boulders of granitic and dioritic rocks and aplite; and he discovered at the south-eastern end of the island a centre of 'alt-vulkanischer' basic eruptives, including diabase and melaphyre-like rocks. On the general conclusions as to the relations of South Georgia, Dr. Heim remarks that the rocks are not sufficient to prove that the island belongs to the folded mountain system of the Andes and Antarctic Andes. Nevertheless, he adds, the appearance of the folded Mesozoic beds, the presence of the tuffs and basic eruptives, and the characters of the associated plutonic rocks in South Georgia and Grahamland form a striking geological reflection of the Patagonian Cordillera.

Since the visit of the German Antarctic Expedition South Georgia has been further examined owing to the public-spirited generosity of Th. Salvesen, Esq., of Leith, by Mr. D. Ferguson, whose work throws much fresh light on the geology of the island and some doubt on the generally accepted view as to its relations. He found in the slates and limestones of Stromness Bay a number of fossils, which have, however, been so crushed that their identification is a matter of extreme difficulty. The fossils include some dichotomous stems which may be dismissed as fucoids. The most definite specimens are some vertical sections through what appear to be massive cylindrical tabulate corals. The best specimen is 45 mm. wide and 70 mm. long; it has thick walls, no septa, and is crossed by thirty tabulæ in a length of 60 mm. The certain generic determination of the fossil is impossible. Its shape was obviously cylindrical; it is above the average size of simple corals; its walls are thick; it has no septa extending far into the interior, but there are traces of septal structure in the wall; and it has no internal vesicular tissue, but many strong tabulæ. This combination of characters is also met with in the coral *Omphyma*. If the fossil be a coral, it

[1] F. Heim, "Geologische Beobachtungen über Süd-Georgien": Zeit. Ges. Erdk. Berlin, 1912, No. 6, pp. 451–6.

would belong to that or some allied genus. Dr. Hinde has kindly examined the specimen, and says that unless it be a coral it is very difficult to say what it can be.

Another group of specimens appeared at first sight the most hopeful of determination. They are cæspitose organisms, of which one tuft is 90 by 100 mm. in diameter; the branches are, on an average, from 3 to 4 mm. in diameter, and they subdivide dichotomously. A section from one specimen shows broken tubuli, which resemble those of monticuliporoids, and the fossil from which this section was cut has a habit similar to that of several genera of Upper Ordovician and Silurian monticuliporoids.

Another series of specimens consist of long unbranched stems, and as their structure seemed to resemble that of sponges they were sent to Dr. G. J. Hinde. He kindly examined them, but declined to accept them as sponges.

A few of the South Georgia specimens were sent to Dr. R. S. Bassler, who kindly examined them and showed them to his colleagues in the National Museum, Washington. He tells me that the opinion there formed is in favour of the specimens being either sponges or fucoids. Dr. Bassler remarks that "one of our Ordovician genera, *Camarocladia*, shows a structure something like these specimens, and for a guess I would say they are nearest this genus. Mr. Ulrich and I agree that they are not Bryozoa, because it is our experience that no matter how great the crushing, specimens preserved as these are show some of the original structure". He agrees that the age of these fossils is probably later than Cambrian and earlier than Devonian. This conclusion is also supported by a small fragment, which, if found in a graptolitic bed, would be regarded as a piece of a monoprionid graptolite. The specimen has been examined by Miss Macphee, who thinks it is probably a fragment of a graptolite; and this opinion is shared by several members of the geological school of this University who have had experience in collecting graptolites in our Southern Uplands. We, however, feel that this fragment is too small for its identification as graptolitic to be anything more than a probability.

The general evidence, then, of this collection is in favour of the calcareous clay-slates of Mr. Ferguson's Lower Cumberland Bay Series, on the north-eastern coast of South Georgia, being either Silurian or Ordovician, though owing to the imperfect preservation of the fossils this opinion is necessarily doubtful. According to Mr. Ferguson the fossiliferous beds rest unconformably on the Cape George Harbour Series, which would be pre-Ordovician or possibly Ordovician. Mr. Tyrrell's description of these rocks shows, however, that they could not have differed greatly in original composition from those of the Cumberland Bay Series.

Above the horizon from which Mr. Ferguson obtained his fossils is a thick succession of sediments, which he regards as one continuous series. Interstratified with these rocks are abundant tuffs, and a diabase sill is intrusive in the Lower Cumberland Bay Series. The igneous centre discovered by Dr. Heim further to the south-east may be the source of the volcanic debris in the Cumberland Bay Series.

During a study of the microscopic structure of these rocks Mr. Tyrrell found a series of Radiolaria in various specimens, and they are especially well preserved in one band. Some sections have been kindly examined by Dr. Hinde. He reports: "The following genera appear to be represented: *Cenosphæra*, *Cenellipsis*, *Amphibrachium*, *Archicapsa*, *Dicolocapsa*, *Tricolocapsa*, *Dictyomitra*, and *Stichocapsa*. The three first-mentioned genera would be included in Haeckel's Spumellaria, the other six in his Legion Nasselaria. At present I should consider from the general character of the forms in these two sections that they are post-Palæozoic and pre-Tertiary in age, and they might come in between the Triassic and the Cretaceous. But this view might be modified by further knowledge from the contents of fresh sections."

Hence the Middle Cumberland Bay Series includes rocks which, according to the Cephalopod, are probably Cretaceous; according to the Radiolaria are probably Jurassic; and according to Mr. Ferguson's fossils the lower division is probably Silurian.

The available evidence, therefore, regarding the geology of South Georgia unfortunately leaves the relations of the island inconclusive. Mr. Ferguson is strongly of the opinion that his three divisions of the Cumberland Bay Series form one continuous succession, and his excellent photographs support that conclusion. Moreover, the similarity between the materials of the three divisions show that they were laid down under similar conditions. Each division, as shown by Mr. Tyrrell's description of the rocks, includes bands of tuff and layers containing Radiolaria, and all these divisions are cleaved, though the rocks of the lower division are much more sheared and altered than those in the two upper divisions. The whole of the Cumberland Bay Series appears to have been formed off the shores of a volcanic land, which included some sedimentary rocks, the debris of which formed the grits and greywackes of the lower division.

The palæontological evidence, however, suggests that the lower division is Ordovician or Silurian, and that the middle and upper divisions are Mesozoic. That at least a part of the series is Palæozoic is supported by the fact that, according to Mr. Ferguson, both he and Dr. Pirie regard the rocks as strikingly similar, lithologically, to the graptolite-bearing rocks of the South Orkneys. We are therefore left with two alternative explanations. South Georgia may consist mainly of Mesozoic marine sediments, interstratified, as in the Andes, with contemporary volcanic material, and the rocks may have been folded and faulted by movements belonging to the Andean System. On the other hand, if the presence of marine Ordovician or Silurian sediments and the absence of Kainozoic volcanic activity be confirmed, these facts would be less favourable to the view that the island is part of the Andean Mountain System. The island might be a folded fragment of the Flabellites Land of Professor Schwarz, and the loop of the Andes which connected Grahamland with Southern Patagonia would have passed to the west of South Georgia. We must await better fossils and further evidence as to the igneous rocks before choosing definitely between these hypotheses.

III.—The Relationship of Isostasy, Earthquakes, and Vulcanicity to the Earth's Infra-Plutonic Shell.

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

THE recent discussion on the origin of the Himalaya, initiated by Colonel S. G. Burrard in his paper "On the Origin of the Himalaya Mountains",[1] has centred in the theories of isostasy and mountain compensation advocated by the Rev. O. Fisher and Mr. J. F. Hayford.

In his latest contribution to the subject Colonel Burrard[2] states very clearly the problem of isostasy now requiring solution—

"Continents and mountains have been found to be compensated by underlying deficiencies of density; how has this condition resembling hydrostatic equilibrium arisen upon a solid globe of rock?"

In a recent paper[3] I have advanced reasons for believing in the existence in the earth's crust at a certain depth, at present unknown, of a highly garnetiferous shell of rock, for which the name *infra-plutonic zone* or *shell* is suggested. This zone is situated at such a depth that pressure becomes a dominant factor in mineral transformations, the accompanying high temperature ensuring a sufficient degree of molecular mobility. It is suggested that under the influence of these high pressures (and temperatures) reactions will ensue between the various ferromagnesian silicates—micas, amphiboles, pyroxenes, olivines—and anorthite felspar, with the formation of garnet as a characteristic mineral: the reason assigned is that a reduction of volume accompanied by an absorption of heat is thereby effected, it being accepted that the garnet-forming reactions are endothermic.

If one can accept the philosophical necessity for the existence of this infra-plutonic shell, then some theory of *isostasy* seems logically to follow, with the garnetiferous plastic-solid shell as the cushion upon which the isostatic adjustments of the earth's crust have their foundation.

For if by tectonic movement the superincumbent pressure be relieved over any section of the infra-plutonic shell, the prevailing high temperature will cause the infra-plutonic rock to liquefy, with considerable increase of volume and evolution of heat (the resultant melt corresponding presumably no longer to the infra-plutonic phase, but to the silicates into which it will freeze on solidification under reduced pressure). This highly heated magma is now available for intrusion to higher levels in the crust according to the direction of application of dynamic pressure, and it may either solidify at higher levels under reduced pressures as a plutonic rock, or it may reach the earth's surface as a lava, either directly, without chemical modification, but, probably, more often only after suffering some degree of magmatic differentiation in intermediate reservoirs.

[1] Survey of India, Professional Paper No. 12, 1912.
[2] Geol. Mag., September, 1913, pp. 385–8.
[3] "Preliminary Note on Garnet as a Geological Barometer and on an Infra-Plutonic Zone in the Earth's Crust": Records Geol. Surv. Ind., xliii, pp. 41–7, 1913.

From the isostatic point of view the chief features to emphasize are: (1) that the infra-plutonic shell is everywhere a potential magma-reservoir; (2) that with relief of pressure any given portion may, with expansion of volume and release of heat, become an actual magma-reservoir; (3) that the molten magma approximates in composition and therefore probably in volume much more closely to that of its plutonic (i.e. non-garnetiferous) phase than to that of its infra-plutonic (i.e. garnetiferous) phase.

It will now be seen that any degree of isostatic compensation of a given column of the earth's crust can be effected by the passage of the requisite amount of rock from the dense, infra-plutonic, garnetiferous phase to the less dense, plutonic, non-garnetiferous phase, or vice versa.

Although this hypothetical garnetiferous zone would maintain a perfect hydrostatic balance in the earth's crust if the superincumbent columns of rock were free to respond as a whole to every small application of stress, it must be remembered that the upper layers of the crust are under lower temperatures and pressures, and are elastic rather than plastic solids, responding to applied stresses by bending and fracturing instead of by flowing. They are consequently able to accumulate a certain amount of strain, this ability accounting at least in part for the imperfect isostatic compensation of parts of the earth's crust.

Earthquakes are now generally regarded as the results of attempts on the part of the earth's crust to release these strains by fracturing, and it is suggested that every large earthquake is accompanied by the passage of a proportional amount of garnetiferous into non-garnetiferous rock, or vice versa, according to the direction of movement of the overlying rock. Although this interpretation of earthquakes follows logically from the foregoing explanation of isostasy, yet it was first suggested to me by Mr. R. D. Oldham in a private communication. He writes—

"I had been searching for some satisfactory explanation of big earthquakes, which seem to require a fairly extensive though still local and fairly rapid expansion in the deeper layers of the earth's crust, and had come across none which had any relation to the actual composition of the earth. The passage from the infra-plutonic to the plutonic mode would give just such an effect as I want."

Judging from Mr. Oldham's letter, the change of phase accompanying earthquakes is predominantly one from garnetiferous to non-garnetiferous (solid or liquid).

Perhaps before closing this note I may permit myself to indicate the bearing of my hypothesis on *vulcanicity*. The present general opinion on the cause of vulcanicity is well expressed by Dr. Harker in the following passage (*Natural History of Igneous Rocks*, p. 37):—

"It appears, then, that we must seek the immediate cause of igneous action, not in the generation of heat, but chiefly in *relief of pressure* in certain deep-seated parts of the crust where solid and molten rock are approximately in thermal equilibrium."

According to this idea the temperature of a molten lava is an expression of the algebraic sum of three factors, namely: (1) the temperature of its solid phase before release of pressure; (2) the latent heat of fusion; (3) the heat changes incidental to the solution of one constituent of the magma in another. But these three factors do not seem to give an adequate explanation of the total heat of some lavas. Basaltic lavas poured out during fissure eruptions, such as those of the Deccan of India, have often flowed superficially many miles from their parent fissures before solidifying; furthermore, before reaching the surface these lavas have doubtless traversed great thicknesses of relatively cool rock continuously abstracting heat. It is difficult to understand how the initial temperature of the magma, based on the three factors referred to in the previous paragraph, could have been high enough to ensure the great fluidity of the basaltic lavas at the surface, in view of the constant losses of heat suffered *en route*; consequently, it seems likely that there is a fourth factor in the heat equation.

The probable exothermic character of the reaction by which the garnetiferous phase of a rock passes to its non-garnetiferous phase (or to its liquid phase) suggests this fourth factor, and enables us to understand how magmas formed by the melting of solid rock due to release of pressure may often possess a surplus quantity of heat due to change of chemical phase above the quantity of heat due to change of physical phase.

I have discussed these questions on the hypothesis that the infra-plutonic shell is characterized by one particular mineral, garnet, that is formed endothermically under high pressure. Further investigation may show the probability of other condensed minerals playing an important part in the same sense as garnet; and, in conversation, Professor R. D. Daly has suggested to me that it would be better not to base my arguments entirely on garnet, but rather on *the general principle of the existence of an infra-plutonic shell composed of dense minerals tending to pass exothermically into less dense minerals on release of pressure.*

Finally, it must be stated that the foregoing notes are intended to form merely a rough statement of the bearing of this hypothetical infra-plutonic zone on the interpretation of the problems of isostasy, earthquakes, and vulcanicity. It is recognized that temperature and water factors must modify the reactions, at least to a certain extent; but it is believed that at the depths under consideration pressure is the compelling factor in chemical changes, the chief function of high temperatures and water (when present) being the ensurance of molecular mobility.

IV.—Cordierite in Granite from Dartmoor.

By F. P. Mennell, F.G.S.

THE presence of cordierite does not seem to have been often recorded from the granite of Dartmoor, in spite of the abundance of that mineral amongst the contact-altered sediments surrounding the igneous mass. The recently published Survey memoirs on Dartmoor and Ivybridge cover nearly the whole area of the granite, and I can only find references to two specimens in which cordierite, or rather pinite pseudomorphs representing that mineral, have been detected microscopically.[1] Within the limits of the granite proper the mineral does not appear to have been observed at all in an unaltered condition, at least so I infer from the absence of any record of it in the above-mentioned memoirs, as I must confess to a somewhat scanty knowledge of West of England geological literature. Having recently done a certain amount of geologising along the northern margin of Dartmoor, which has not been investigated by the Survey since the introduction of modern petrographical methods, and having obtained some rather interesting results, of which I hope to publish shortly a detailed account, I was glad to take advantage of an opportunity presented by a visit to the South of Devon to make some comparisons with the contact and other phenomena described by the Survey.

One of the excursions made with this object was to Ivybridge, where the chiastolite slate is well known to geologists and where the other andalusite-bearing rocks have been well described by Mr. Barrow. Going up from the railway station alongside the Erme valley, over the track which leads past a quarry where the chiastolite slate is well exposed, one soon comes upon the granite, of which a second small quarry affords an excellent section, close to its margin. Nearest the contact the rock is even-grained and rather discoloured by alteration. Further away, however, a fresh, grey, biotite granite with large white pseudo-porphyritic felspar crystals is seen. Through this are sparingly distributed idiomorphic six-sided or somewhat rounded stumpy prisms of a dark-green mineral, often $\frac{1}{4}$ to $\frac{1}{2}$ in. in length. The habit and general appearance of the mineral are quite sufficient for its identification as cordierite, though the exceptionally well-marked basal parting gives some of the specimens a rather unfamiliar aspect. Many of the crystals are semi-transparent and glassy-looking, and even the more altered of those which are conspicuous in hand specimens are, for the most part, colourless and transparent in thin section except round their margins. They show, however, here and there, some regularly distributed brownish enclosures like those seen in diallage. Faint yellow pleochroic halos are also occasionally seen, as well as some yellowish stains which are not pleochroic. The smaller crystals, that is to say, those which are only a millimetre or so across, are altered throughout to greenish matted 'pinite' aggregates. A specimen which I secured, but have not sliced, contains a little rounded patch about $\frac{1}{3}$ in. in diameter, consisting of fresh cordierite and a reddish mineral which I take to be andalusite. The latter is very common in the adjacent contact rocks, and I have found it to be abundant along the northern margin of Dartmoor in certain offshoots of the granite, but it is curious that this fine example of a granite containing fresh cordierite in conspicuous crystals should be found where that mineral does not seem to have been detected among the metamorphosed sediments.[2] It may be surmised that the absorbed material, which has recrystallised in part

[1] Dartmoor memoir, p. 38. Mr. L. J. Spencer kindly ascertained for me that there is no British specimen of unaltered cordierite in the National Mineral Collection.

[2] The word cordierite does not appear in the index to the Ivybridge memoir.

as cordierite, came from a higher horizon than is now left exposed. It may perhaps be noted that tourmaline is comparatively rare in the rock, although the sediments at the immediate margin are much tourmalinised and have been so altered in the process that all the original andalusite has disappeared. Its rarity may well have something to do with the freshness of the cordierite, as I had already been led by a study of the Cape Town granite to attribute to processes connected with tourmalinisation the conversion of that mineral into aggregates of 'pinite'.

V.—Ice-flows in the Trent Basin.

By R. M. Deeley, M. Inst. C. E., F.G.S.

In 1866 I communicated a paper to the Geological Society of London on the Pleistocene Succession in the Trent Basin. The boulder-clays and outwash deposits of this district are of two distinct kinds, the one containing rocks from the west and north-west, and the other boulders etc., from the east or north-east of the district. In all cases, except where they have been ploughed up and re-arranged by the ice itself, the drifts containing westerly rocks only are the lowest, and the drifts with easterly rocks have been spread over them. We thus have two distinct ice-flows to deal with.

I contented myself in 1886 with describing the nature of the deposits, the conditions under which they were formed, their succession and the ice-flows they indicate; no attempt being made to explain how the variations in the direction of the ice-flows arose. For some years doubts were felt by many as to the constancy of the succession described, it being considered that the Trent Valley was an area in which the easterly ice-flow met the westerly flow, and that the deposits merely indicated that in this area the ice-flow from the west overpowered the flow from the east and vice versa. The mapping of the area, however, by the officers of the Geological Survey confirmed my general conclusions, that the westerly drifts were the first to be laid down and that the easterly drifts were subsequently spread over them.

Harmer suggested that the westerly ice passed down the Trent Valley in the first instance, and that it was at a later date thrust back by the great ice-sheet which crossed the German Ocean from Scandinavia. Such an explanation at first sight appears very feasible; but the nature of the deposits, and their arrangement with regard to each other, does not appear to me to admit of such an explanation; for had the area been entirely covered by ice, the direction of the flow of which varied, boulder-clays and mixed gravels only would have been formed; whereas each kind of boulder-clay is accompanied by its own kind of outwash gravels and sands.

Since 1886 our knowledge of the nature of the deposits formed by glaciers, and the method of their formation, has been very greatly increased. Alaska, Greenland, Spitzbergen, and the Antarctic area have all been more or less explored, with the result that glacial problems have had a good deal of light thrown upon them. But even now, when we come to deal with such an area as that of the Trent Basin or the south-eastern counties of England, there are great difficulties to be faced. In the present paper a *tentative* attempt will be made to show how, through the peculiar ice movements, the arrangement of the deposits indicated came about in this area.

In the Trent Basin there is a series of boulder-clays, gravels, and sands, which occur in the same order throughout the whole of the area, and in many cases all the members may be found within a few miles of each other. Perhaps in no one section is the whole succession shown; but in very many instances several of them may be seen superimposed the one upon the other.

The succession, commencing with the most modern, is as follows:—

Chalky Gravel.—Sand and gravel, with flints, rolled chalk, etc.
Chalky Boulder-clay.—Tough bluish boulder-clay, containing chalk, flints, and other easterly rocks: some derived from older boulder-clays, sands, or gravels.
Melton Sand.—Thick sand beds, with chalk and flint.
Middle Pennine Boulder-clay.—A tough boulder-clay containing well-striated rocks from the west and north-west only.
Quartzose Sand.—Clean false-bedded sand and gravel up to 20 feet thick, quite free from flints.
Early Pennine Boulder-clay.—Reddish, silty, tough boulder-clay, with striated westerly and north-westerly erratics.

Some of the well-stratified sands and gravels I now consider to be distinct from the Quartzose Sand. Those at Kirk Ireton, Spondon, and Grantham are cases in point. They are most likely outwash gravels of the Middle Pennine Boulder-clay. All the sands and gravels are quite free from contemporaneous molluscan remains. Even the clean, false-bedded sands are free from all such signs of life. In this respect they resemble the outwash deposits of modern glaciers and the sands and gravels of glacier-dammed lakes. As has been already stated, their most marked peculiarity is that they consist of two distinct kinds of boulder-clay and gravel, the upper series being derived from the east and the lower from the west and north-west. This great disparity in the nature of their rock contents induced me in 1896 to regard them as belonging to two distinct epochs of glaciation. I am now, however, of the opinion that they all belong to one great period of ice advance and retreat, which was probably marked by considerable but minor oscillations of the ice-front; for although the area might appear to be anything but a marginal region of the ice-flow it really occupies such a position.

As far as England is concerned, the distribution of the boulder-clay and moraines seems to show that the ice-margins paused, on two separate occasions, along different lines. These two lines are regarded by many, and for good reasons, to be the margins of the maximum extension of the ice-sheets of two different periods. Whether this be the case or not, these two ice-margins throw very considerable light upon the problem with which we have to deal.

In the Figure is shown the probable ice-margin in the British Isles and the North Sea during the time the Purple Boulder-clay was formed. The British ice is then considered to have filled the Irish Sea Basin and mounted the watershed between the Trent Valley and the Cheshire Plain. If there were several periods of ice advance they probably all went through this stage before reaching a maximum. With increasing cold we may imagine that the Irish Sea ice at *a* (see Figure) passed into and down the Trent Valley before the Scandinavian ice-sheet (*b*) reached it from the other direction. Indeed, the Irish Sea ice may have collected rapidly, being in the track of the moist Atlantic winds, and arrived at its maximum development and formed the Early Pennine Boulder-clay long before the Scandinavian ice-sheet reached the Trent Valley area.

But upon this Early Pennine Boulder-clay there rests the thick bed of false-bedded Quartzose Sand. This deposit, there is good reason to suppose, was deposited in open water which was flowing from the west. The retreat of the ice-margin to the west again, the Quartzose Sand indicates, may have been due mainly to a slightly warmer interval supervening. We must, however, assume that the water-level in the Trent Basin was considerably raised, or the fine sand beds would not have been formed. Such a ponding up of the water-level might have been the result of the blocking up of the North Sea by the Scandinavian ice-sheet. Whether the Straits of Dover then existed and the water-level was raised over a large area of the south-east of England, or whether the ice merely ponded up the water in the Trent Valley, is not certain. The creation of a glacial lake in the Trent Valley would of itself tend to melt off the western ice-lobe, issuing from the basin of the Irish Sea, and cause it to retreat, in addition to the melting produced by a temporary amelioration of the climate. The latter was probably the most effective agent of change.

At the end of the Quartzose Sand stage the climate became colder and the western glacier-lobe readvanced. A sand-pit in the Quartzose Sand at Aylestone, south of Leicester, showed a thick bed of fine current-bedded sand covered by reddish boulder-clay containing

Charnwood rocks. These had in many cases been clearly dropped on the bottom of the lake by shore-ice from the Charnwood Hills. Indeed, Charnwood rocks are found many miles north of the Charnwood area in places to which glaciers could not apparently have carried them. They were most likely spread abroad during the time of the existence of this glacier-dammed lake.

The return of colder conditions, on the passing away of the short warm period during which the Quartzose Sand was formed, led to the return of the ice from the west, and the Middle Pennine Boulder-clay was spread over the earlier drifts. The ice of this stage went a long way west, at least as far as, or even beyond, Lincoln.

The Middle Pennine Boulder-clay is a very widespread deposit. The ice-sheet in the Irish Sea Basin, in addition to reaching the Trent Basin over the low watershed to the south-east, passed over the high watershed at Dove Holes, near Buxton, flowed down the Wye and Derwent Valleys and joined the main ice-stream near Derby. Boulder-clays of this age have been found near Bakewell, where well-scratched and distant erratics are numerous. Another patch of boulder-clay of this age is to be seen at Crich, resting upon a glaciated limestone surface, the striæ indicating a flow down the valley. Erratic boulders and boulder-clay also occur on the limestone area of the High Peak. The Crich deposit contains many distant erratics, as well as large polished and striated boulders of mountain limestone, etc.

Following the formation of the Middle Pennine Boulder-clay, a rise of temperature would seem to have come about, for the glacier-lobe retreated to the westward. But this amelioration does not seem to have stopped the flow of the ice from Scandinavia. This ice then advanced over the Middle Pennine Boulder-clay and outwash gravels, and laid upon them thick deposits of boulder-clay, silt, gravel, and sand. The sand and gravel occur, apparently, at all horizons in the Chalky Boulder-clay, but is most strikingly developed towards the bottom and top. The lower deposit, the Melton Sand, seems to have been deposited in open water. I never found any evidence favouring the assumption that the easterly and westerly ice ever met. Indeed, the westerly ice would seem to have retreated very rapidly indeed, and led to the formation of a glacier-dammed lake in the south-westerly portion of the Irish Sea, before the Scandinavian ice had reached its maximum extension. It was during the maximum extension and retreat of the Chalky Boulder-clay ice that the Chalky Gravel was formed.

How far to the west the Chalky Clay and its associated deposits extend beyond Burton-on-Trent I do not know. The water from the glacier lake, however, seems to have been in communication with the Irish Sea Basin lake at Rudyard, and to have overflowed into the Severn Valley, probably by the low cut south of Henley in Arden.

It is probable that the time of maximum cold did not coincide with the time of the maximum extension of the ice. Even in the case of our winter and summer, the lowest and highest temperatures do not coincide with the shortest and longest days. The warmest day occurs about a month after the longest day. Similarly, the greatest extension of the glaciers occurred some time after the time of lowest temperature, and the Scandinavian ice-sheet may have reached its greatest extension when the British ice was melting away.

Britain, being near the edge of the continental shelf, would respond more readily to temperature changes than the Scandinavian ice-sheet to the north-east. It may therefore have happened, as has been suggested above, that the British ice was on the wane long before the Scandinavian ice reached its greatest extension.

Temporary changes of temperature would also tend to affect the margins of the ice-sheet rather than the centre of the area of dispersion. It thus seems to have come about that the maximum extension of different portions of the ice-margin occurred at different times, and that temporary slight ameliorations of climate affected the margins of the ice-sheet supplied by the British mountains more than they did the marginal portions fed by the Scandinavian ice.

If this reading of what took place be correct, we must not regard a map showing the ground which had been covered by the ice-sheet at maximum extension as indicating the actual extent of the ground covered by ice at any one time, for it would appear that when the North Sea ice reached the neighbourhood of London the glaciers from the British mountains were already on the wane.

VI.—Professor Walther's Erosion in the Desert considered.

By W. F. Hume, D.Sc., F.R.S.E., F.G.S.,
Director of the Geological Survey of Egypt.

(*Concluded from the January Number, p. 22.*)

SECTION 15 deals with the very interesting subjects of *desert films* and *crusts*. Two features are very noticeable in many desert limestone rocks, the production of a hard crust on the outside and of a powdery soft interior. The outer hard layer is often of different colour from the internal portion and highly polished. Professor Walther points out that such hardened crusts occur in buildings in Central Europe, where he suggests that during the dressing of the stone the fine powder produced has been so driven into the pores that chemical agencies are no longer as active. I ventured a suggestion for the production of such sub-crystalline surfaces where much exposed to the sand-blast in which action such as the above was vaguely present to my mind, but whatever external physical effect such external activities may have, the more important is undoubtedly the concentration of solutions near the surface under the influence of the solar heat.

Where erosion along cracks has been of long duration the hard layers may alone be left, giving rise to various gnarled and contorted structures in the rocks which are a characteristic feature in desert limestone weathering.

In a brilliant word-picture (p. 142) Professor Walther draws the contrast between a European and a desert landscape. In the first case a broad covering of green gives the fundamental colour tone. In the desert scene, on the contrary, yellows and browns in every shade from delicate golden yellow to the deepest coffee-brown or umber are dominant, and even where vegetation is present the tints of green pass insensibly into delicate shades of grey. Only at sunset is the stern scene for a short period replaced by the riotous colouring of a brilliant fairy-land, then with the fall of night the pall of a great desolation is spread over the wild and inhospitable waste.

This year as we steamed down the Gulf of Suez, past the granitic hills of Gebel Zeit, there stood by me three earnest geological students on their way to study the intricacies of these desert regions. In front of those rugged ranges were low foothills of dark and forbidden aspect. "And what are those?" asked my companions, as they gazed on their sombre outlines, recalling the outpourings of some destructive volcano. As I replied "Raised coral-reefs" a silence fell, and it was evident that the questioners found it difficult to believe the statement. Later on, at Abu Mingar, one of them was deeply impressed when he found these strangely scoriaceous masses filled with fossils of the most pronounced character, and realized that the blackened surface was but a thin crust on a limestone which had been eroded by sand and chemical agencies.

Professor Walther distinguishes three types of desert films. The first is the *dust film*, due to the fine dust driven with great force against the rocks. This forms a thin covering, giving a yellow tint to many of the snow-white limestones of Egypt, this being a case therefore where the colouring of the stone comes *from without.*

Most striking is the second group of *cataract films*, beautifully displayed in the cataract regions, where a brilliantly polished crust of graphitic appearance spreads over igneous rocks of every shade and type. Taking as his basis the well-known memoir by Lucas (misspelt Lukas in the text) on the "Blackened Rocks" of the Nile Cataracts, he points out that the materials recorded (much manganese dioxide, ferric oxide, lime, silica, magnesia, with traces of potash, sulphuric and phosphoric acids) are such as would occur in the rocks themselves, which are permeated with water at high Nile. The solutions so formed are subsequently evaporated during the low-water period, with deposition of the dissolved substances as a thin surface film.

In Professor Walther's discussion of this subject he has assumed that the crusts are only formed on igneous rocks. This is not, however, the case, for at Ragama, near Kom Ombo, some distance north of Aswan, a white chalky limestone is blackened to a remarkable extent. In this case it seems difficult to imagine that the film is due to evaporation of internal solutions, and the question cannot yet be considered as finally settled.

The third type, the brown *protective film*, is one of the most characteristic features in desert regions. Its formation is frequently capricious. Fossils in rocks often stand out, intensely blackened, from a light-tinted limestone, and siliceous limestones display the darkening better than finer varieties. The crust is purely a surface one, and only a millimetre thick. It often gives a blood-red or yellow streak, indicating iron oxide where the colouring is yellow or grey; hydrated oxides of manganese and iron are dominant. The brown crust marks the beginning of the change, the red one is the same after loss of water, the addition of moisture restoring the yellow coloration. In manganese films the streak remains grey, whether the rock be moist or dry. The iron and manganese oxides are mutually replaceable. Professor Walther (following Sickenberger) also cites a case from Dakhla where the crust contained 8 per cent of cobalt, this originating from the thermal springs there.

The gradual development of dark protective films is well shown in the biconcentric circular flints (Augensteine) which are well illustrated in figs. 82–5, showing the progressive stages in depth of colour. The causes noted as producing these results are traces of moisture in the rocks and intense heating by the sun, the water contained in the deeper layers being drawn in a capillary manner to the surface. This moisture acts on the salts of iron and manganese, bringing them into solution, these being redeposited on the surface by evaporation. That the dark colouring is frequently observed on fossils when their matrix is far lighter in tint is ascribed to the presence of phosphoric acid, derived originally from the organisms, while in addition silicic acid in the crystalline rocks and phosphoric acid in the limestones are stated to have such an affinity for iron and manganese oxides that at the point of contact chemical action is set up, which retains the oxides, while the chlorides are removed by the wind.

At p. 149 Professor Walther combats the view that the desert films are directly due to rain or dew. Had this been the case, these should become less marked in passing from the Nile Valley into the arid desert, and again reappear in the region of the oases. On the contrary, his experience has been that the brown crusts become less marked as the more rainy districts are approached, and the films are therefore essentially rainless desert structures, due to the evaporation of highly concentrated solutions under the influence of the high temperatures.

While agreeing with the general proposition, I am certainly under the impression that the crusts are more marked in that portion of the desert near the Nile Valley. The oases occupy so small an area in the Sahara that their effect in any case would be almost negligible.

Section 16 deals with Erosion by Water, in which it is mentioned that such streams as the Nile and the Colorado are in reality strangers in the great desert system, the former especially being similar, in all respects, to streams in the humid or pluvial regions, and only differing from them by its long traverse across the desert belt. The essential feature determining erosion by water in the desert is the sudden rain-storm, and the point is emphasized by illustrations taken from the neighbourhood of Helwan, in the Sinai Hills, and the Kharga Oasis. The activity of the rain is short-lived, but intense while it lasts. Years, nay centuries, may elapse, before another storm breaks in the same locality, and in fig. 93, the Ras-el-Kadi (in Kharga Oasis), an illustration is given of such a torrent-conglomerate based on soft clayey strata, which have undergone sand erosion, leaving the torrent-conglomerate as the head of a 'mushroom', of which the stalk is composed of the clays. In desert rain-storms an essential feature is the widespread character of the torrent, to which MacGee has given the term of 'sheet-flood' and Passarge of 'Flächenspülung' (p. 163), the waters not following definite channels, but extending in broad sheets over the whole surface. As a result, delta-like deposits are produced at the mouths of the valleys, the Cooper Creek delta in Australia, originally described by Eyre, being given as an example of such a feature, which far exceeds in extent the great river deltas of the Nile and the Danube.

Section 17 is devoted to *Deflation*, or the *activity* of *wind* as a *transporting agent* of the light materials formed by erosion or composing the softer rocks. This agency Professor Walther considers to be the most important of those acting in desert regions.

An illustration is given of the beginning of a dust-storm on an Australian farm, but equally good examples are available from the Sudan, very fine photographs having been taken of such phenomena at Khartoum. Dust is carried for hundreds of metres into the air, a sand-storm when viewed from the summit of a hill above its influence being an impressive and awe-inspiring spectacle. Personally I entirely agree with Professor Walther as to the importance of deflation in the Libyan Desert; in the Eastern Desert of Egypt water action is probably as effective a factor.

One of the noticeable effects of sand-laden winds is the formation of hollows (often arranged in network patterns) in the faces of sandstone cliffs or on the sides of granitic outliers. Walther, following Futterer, maintains that it is a mistake to ascribe their genesis to the action of sand blown by wind only; in the majority of instances the cavities have been formed by the effects of insolation on the solutions in the rock, the weathered material due to the action being then carried away by the wind. In this way granitic blocks may be completely eaten through, giving rise to arched cavities. If these processes be continued the rocks are eventually worn down to isolated blocks of remarkable shapes, in which the 'mushroom' form predominates.

Sections 18–20 deal with the character of the desert surface resulting from the sweeping away of all the lighter materials by the wind. A series of illustrations exhibit the character of the great plains in the Western Desert and Ethiopian region due to the removal of the finer particles where limestone and conglomerates are predominant; in the sandstone regions a vast expanse is produced, out of which rise isolated tabular outliers, sometimes protected by a hard ferruginous cap.

In Section 20 Professor Walther establishes five diverse regions as regards the forms produced by denudation and their geological history.

1. The *Serir*, in which strata of sand and flint pebbles or boulders have formerly spread over the surface. From these beds the sand has been removed, leaving a waste of large fragments embedded in the soft material which still remains. This *flint* desert gives rise to gentle undulations in which no conspicuous features are developed, and is characteristically displayed to the west of the Pyramids.

2. The *Hamada* is a region where hard limestone bands alternate with softer bands of marl and clay. The limestone beds form hard surfaces, which, remaining after the removal of the softer strata, give rise to broad and desolate plains extending unbroken in every

direction. Change to a higher limestone stratum is marked by a low step only a few metres in height, leading to another extensive plateau in which the *hamada* character is faithfully reproduced. Professor Walther could have carried his description further, for these surfaces vary according to the nature of the limestone stratum. Sometimes the desert floor is entirely composed of fossil remains, oysters or nummulites, at others of sun-warped sub-crystalline limestone scoured deep and even cut into long hummocks by the wind-borne sand.

3. The third place is given to the Wadis or Dry Desert Valleys, special attention being called by picture and description to their precipitous terminations, often in great amphitheatres. In the formation of these deep ravines, erosion by water and deflation are regarded as both having taken part, the mighty effects of one day of rain-storm being followed by the activities of the wind during long periods of dryness. Here main channel and tributary have little meaning, and valley slope is often difficult to determine, except in the major watercourses of the country. Narrow ledges often separate two branches until some great rainfall sweeps them away. If these sudden torrents are so effective in the dry sun-cracked wilderness, the greater streams, such as the Colorado and the Nile, must be more intensely destructive, and erosion works on a scale to which no parallel exists in more temperate climes.

4. From the valleys, eating backward into the desert plateaux, there is but a short step to the *Outliers*, which, first extending as bold and precipitous projections from the main cliff face (Zungenberge), (see fig. 120, p. 205), finally become separated, forming isolated hills. In this section it is necessary to point out that a factor works of which, if I mistake not, Professor Walther has taken no notice.

In the Lower Eocene series huge masses of limestone rest on clays. The rain falling on the plateau surface percolates through the limestone and forms a water-cushion over the impermeable beds beneath, upon which the heavy superincumbent strata tend to slide. This geological factor is of the highest importance in a wide region of Upper Egypt.

5. Naturally the great depressions of the *Oases* attract special notice, and Professor Walther holds that after weighing all the facts there is only one conclusion possible, viz. that the whole of the mass of material removed from these areas has been carried away by the wind. This seems to me to assign far too important a rôle to deflation, and to ignore the vast amount of marine erosion which must have taken place during the elevation above sea-level of the strata deposited during Eocene and Cretaceous times.

6. The Nubian Sandstone scenery is mentioned in which pyramidal and tabular outliers rise out of vast plains with compact floors composed of the coarse grains not carried away by the wind. In the Geological Survey memoirs it has repeatedly been pointed out that many of the longitudinal valleys in the Eastern Desert of Egypt owe their origin to the presence of the Nubian Sandstone, and result from its easy denudation, while further south this formation is traversed by fine ravines where the transverse valleys draining from the Red Sea Hills cross it on their way to the Nile.

7. In the next section Professor Walther touches very lightly on erosion forms in Sinai and the Arabian Desert, again referring those produced to the influence of water-action and deflation. This section deals with an area so complex and so varied that it might itself without great difficulty be raised to the rank of a volume; but to understand the origin of the stupendous precipices of the Red Sea Hills and the Red Sea depression, the varied features due to dyke-ridges, and the wearing of soft veins of basic rock, or the spreading of gravel plain and ancient coral-reef, requires a clear conception of the earth-movements which have made this remarkable region what it is. Only as the result of the giant earth-creep by which the underlying granitic masses have risen high above the depression of the Gulf of Suez, and the breaking up of a mighty anticline, have we the basis on which rain-storm and deflation, chemical change and sand-scouring are able to work. Marine erosion and tectonic changes of the first magnitude have produced the surface features which have acquired the present desert characteristics by processes so ably described in the volume under consideration.

REVIEWS.

I.—The Life of the Mollusca. By B. B. Woodward, F.L.S., of the British Museum (Natural History), Past President of the Malacological Society of London. 8vo; pp. xii and 158, with 32 plates and a map. London: Methuen & Co., Ltd., 1914. Price 6*s*.

WHEN I was but a youthful aspirant in science I received from Dr. S. P. Woodward a present, in three parts, of his *Manual of the Mollusca, a Treatise on Recent and Fossil Shells*[1] (1851–6). When bound it was only $7\frac{1}{4} \times 4\frac{1}{2}$ inches in size, with 530 pages, 25 plates, and 272 text-figures. The mass of matter squeezed into it was enormous—much more so than the publisher bargained for! I thought it the most wonderful book I possessed, next to Darwin's *Voyage of the "Beagle"*.

That this little work should have held its place as a scientific text-book for sixty years seems almost past belief, and speaks volumes for the great mass of valuable biological facts contained in its small and closely printed pages. Numerous other works on malacology have since appeared, of greater or less importance, by Lovell Reeve, Forbes & Hanley, Henry and Arthur Adams, J. Gwyn Jeffreys, G. B. Sowerby, and lastly by Dr. Paul Pelseneer (author of one of Sir Ray Lankester's Zoological Treatises, part v, 1906), etc., proving that a large section of the public still pursues the study of the Mollusca beyond those perennial lovers of oysters who date back even to our prehistoric ancestors.

[1] It formed one of "Weale's Elementary Series" (afterwards transferred to Virtue & Co.), and of which between 1851 and 1880 upwards of 11,000 copies were sold. In 1880 a fourth edition, price 7*s*. 6*d*. (edited by Ralph Tate), was published by Crosby Lockwood & Co. (its last owners), in which several fossil genera of Mollusca were added in an appendix and the Tunicata removed, but the Brachiopoda retained!

In France Fischer's *Manuel de Conchyliologie* (Recent and Fossil), in eleven fascicules (from 1880 to 1887), with 1,369 pages and 1,139 text-figures, embraces all Woodward's original work, besides very much additional new matter. Chenu's large *Manuel de Conchyliologie* is more valuable for its numerous and beautiful illustrations (many in colour) than for its text.

The establishment of the Malacological Society of London in 1893, now in its twenty-first year, with a published journal of ten volumes, speaks highly for the advance in the scientific study of the Mollusca during the past half-century all over the world.

In days of long ago our neighbours the Dutch were not only the earliest voyagers, they also took the lead in collecting and purchasing rare and valuable shells; but they knew little or nothing about the animals themselves. They were rather like the lady at the "Zoo" who, seeing a hermit-crab in one of the tanks walking about in a whelk-shell, remarked to her daughter how interesting it was *to know* the little animals that *made* those shells.

Even in the days of Robert Macandrew and Gwyn Jeffreys, to collect shells and remove the animals without injuring the test was rather the be-all and end-all of those early conchologists. Edward Forbes, S. P. Woodward, Huxley, Lankester, Paul Pelseneer, Godwin-Austen, B. B. and Martin F. Woodward, and the modern school of zoologists have shown by their published works and lectures that a classification of the Mollusca, based upon an accurate knowledge of *the shells alone*, would be as satisfactory as a tailor's knowledge of a new client derived from inspecting a suit of his cast-off clothes.

In the present work the author tells us his object is "to give a succinct account of what is known concerning *the life* of that branch of the animal kingdom to which the snail, the oyster, and the cuttle-fish belong—the Mollusca". But it is not an easy matter to express in a few words the general characters by which any group or phylum of the animal kingdom can be distinguished from its neighbours. To illustrate this difficulty we may cite the fact that some fifty years ago the Cirripedia, the Tunicata, the Brachiopoda, and some operculated corals (*Calceola*, *Goniophyllum*, etc.) were included in the Molluscan sub-kingdom. "Externally most molluscs possess a 'head', a ventral creeping organ, the 'foot', and a dorsal covering, the 'mantle', which bears and secretes the shell. This shell forms a protection to the more vital organs, and into it the animal can generally withdraw for security from attack. The mantle does not usually reach far beyond the shell-margin when the animal is extended, but in some cases it curls round over the shell (e.g. *Natica*), and even as in the cowry (*Cypræa*) meets on the top. In the more specialized Mollusca there is a tendency to the reduction, even to disappearance, of the shell, and in these there is a corresponding liability for the shell to become more and more enveloped permanently in the mantle as the animal becomes less and less able to use it as a place of retreat" (p. 2).

It is surprising to find how full of interesting matter are the living Mollusca when studied as a whole, not merely as dry shells in a cabinet. Take, for example, chapter vii on the evolution of the Mollusca, and quite a new set of ideas are presented to the student.

Thus one is led to consider where the mollusc began to take up his abode, and it is suggested that the tidal zone was in all probability the cradle of the race. "From the shore-line the various members betook themselves to probably deeper and deeper water on the one hand, but also, though perhaps more tentatively and gradually, to fluviatile and terrestrial conditions on the other." Thus we see the early human infant begins his marine efforts by 'paddling', and it is long before he attempts deeper water or, like the Argonauts of old, risks a pelagic adventure far from land. From the earliest times soft-bodied (molluscous) animals have doubtless been attractive to their fellows as well as to the early nomads who lived upon the waifs and strays which the waves cast up upon the shore. The shell of all types, univalve, bivalve, and multivalve, were a necessity to these early molluscs. "Primarily among the inhabitants of a rough foreshore the massive strength of the shell is noticeable, the object being of course to withstand the battering action of the waves and hard substances, like stones, cast up by them" (p. 103).

The limpets with their tent-shaped shells afford an example of an excellent protective form of covering for a surf-dweller on rocks. The *Trochus*, Turbos, and Neritas among spiral forms have usually stout shells and often also a shelly operculum or door to their houses. Such forms as *Littorina*, *Purpura*, *Nassa*, *Pterocera*, *Turbinella*, and *Strombus* require much sea hammering to break their shells. In deeper water, however, where no surf breaks, the thick heavy shell of the Gastropods ceases to be of service, and the inhabitants adopt a much thinner and lighter covering (p. 104).

Among the bivalves (Pelecypoda) also the shore frequenters often have very stout and convex shells, like the Giant Clam (*Tridacna*) and the *Hippopus*, and can withstand the full beat of the ocean waves; so too could the Rudistes among the fossil reef-building molluscs. But "most of the Bivalves, as a matter of fact, do not live in exposed situations, but burrow more or less deeply into soft sand or silt". Those that do not penetrate to any depth below the surface, nor live in deep water beyond the reach of ground-swells, such as the Cockle, *Cardium*, the Veneridæ, etc., are often disturbed by storms and thrown up alive upon the beach. Their activity, however, frequently enables them to get back (by walking with their foot) into their briny home, where they quickly bury themselves once more in the sand.

All sections of the group except the bivalves have a distinctive feeding organ, the 'radula'. It occupies the same position in the mouth as does the tongue in the higher animals, and consists of a series of recurved teeth, formed of dense chitine, attached in transverse rows to a membrane of the same substance. "The number of teeth in each transverse row varies from one in certain sea-slugs to upwards of two or three hundred as in the 'top shells' and their allies (*Trochus*, *Haliotis*, etc.)" (p. 11). The whelk has about 250, a big limpet 2,000, the periwinkle 3,500, the common garden snail 15,000, and the big grey slug 26,800. As in the higher animals, "the form of the teeth are some index to the diet of the animals, the purely herbivorous having short broad-pointed teeth, the carnivorous sharp-pointed teeth, which in those feeding on *living animals* are barbed to retain their prey, while in the Cones the teeth are not only barbed but perforated and connected with poison glands."

"In habit the Mollusca are far from active, only some of the cuttle-fishes being capable of spasmodic rapid motion, so much so that the term 'sluggish', borrowed from them, best describes them." (p. 13.)

Let us now turn to the geological history of the Mollusca. In chapter iii Mr. B. B. Woodward tells us these animals made their appearance very early in the world's history, the more generalized forms preceding the more specialized. In the oldest fossiliferous beds of the Lower Cambrian only a few representatives have been found. These consist of some limpet-like shells (*Scenella, Stenotheca, Platyceras*); also a turreted convolute shell (*Raphistoma*), and the remains of two bivalves.

In the Upper Cambrian further examples of the early Rhipidoglossa are found (*Murchisonia, Cyrtolites, Owenella,* and *Straparollina*), as well as one (*Trochonema*) a supposed member of the higher one-gilled section of that sub-order. Already, too, seven species of Cephalopoda had made their appearance, all belonging to the more primitive straight-shelled section of the Nautiloidea. In the succeeding Ordovician epoch Aspidobranch Gastropods predominated (*Cyclonema* and top-shells, Turbinidæ), and the first Chiton appears (*Priscochiton*). The Cephalopoda are represented by sixty-five species of Nautiloidea, mostly straight-shelled, but some curved and a few coiled forms.

Considerable increase in the Mollusca occurs in the Silurian epoch. Members of three families are added to the Gastropods, and of Pelecypods Palæoconchs were most abundant. Two more Chitons appeared and some doubtful Scaphopods. "The Nautiloidea attained their zenith with about 230 species, among which the coiled were almost as abundant as the other shell-forms. From that day the group has steadily diminished in numbers, only five species now existing"—probably not so many.

In the Devonian strata there is a still further increase of the Pelecypoda (Trigoniæ, Pectinidæ, Mytilidæ, and many others). The first freshwater mussel, *Archanodon Jukesii*, appears, closely resembling the modern *Anodonta* (swan mussel) of our ponds and lakes. A true *Dentalium* and representatives of the more primitive Ammonoidea (*Clymenia*) and Goniatites appear in the Devonian epoch. At its close land-snails (*Strophites, Dendropupa*, etc.), allied to the chrysalis shells, have been found in the plant-beds of St. John's, New Brunswick. The Coal-measures of the Carboniferous period have yielded some other interesting air-breathing snails (*Dawsonella*, etc.), the first brackish-water snail (*Ampullaria*), a freshwater snail (*Physa*), and a small land shell (near to *Pyramidula*), a common form to-day. Many examples of freshwater bivalves (Cardiniidæ) were plentiful in the Carboniferous; the oldest Tectibranch (*Cylindrobullina*) has been obtained, and a highly specialized bivalve (*Lithophagus*) that burrows into rock, shell, or coral.

Although at the close of the Palæozoic period many of the older genera of bivalves disappeared, at the opening of the Mesozoic period in the Trias a number of others came in. Among them we find more species of freshwater mussels (*Unio*), of the thorny oyster (Spondylidæ), and cockles (Cardiidæ). The oldest examples of the ten-armed cuttlefish here made their first appearance.

"The Jurassic strata are rich in molluscan remains, which sometimes form whole masses of rock. The Gastropods attained their acme of development at this period. Further land shells and the earliest freshwater Gastropods (*Planorbis*, *Valvata*, and *Melania*) have been recorded from the lowest Jurassic beds, but of their exact determination there is some doubt. In the uppermost beds, however, the well-known Purbeck Marble is composed of masses of *Valvata*, *Vivipara*, etc." (p. 48.)

"Among Bivalves genuine Ark Shells (*Arca*), *Anomia*, and various families of Eulamellibranchs, including the freshwater Cyrenidæ, made their appearance; while if *Corburella* be admitted as a member of the Septibranchia, that order must be added for the first time. The 'pens' and ink-sacs of earlier members of the *Sepia* tribe (*Beloteuthis* and *Geoteuthis*) are first found in the Lias, with the remarkable Belemnites whose 'guards', often called 'thunderbolts', are familiar fossils.

"In the succeeding Cretaceous period further development took place. Among the Gastropods there was a decided increase in the higher Pectinibranchs, including representatives of most of the families of Rhachiglossa. Amongst Bivalves two most remarkable aberrant families (Radiolitidæ and Hippuritidæ) were confined exclusively to this period. Externally these look not unlike simple corals with a lid, while internally they display highly peculiar modifications. Numerous other Eulamellibranchs, including some boring forms such as Petricolidæ and Saxicavidæ, as well as the Razor-fish (*Ensis*), arose, with an undoubted representative of the Septibranchs (*Leiopistha*). An Octopus (*Palæoctopus Newboldi*) standing for the highest Cephalopods was revealed for the first time in the Cretaceous of Mount Lebanon, but, on the other hand, the Ammonites and Belemnites died out.

"During the Tertiary epoch the Rhachiglossa and Toxoglossa became the dominant Gastropods, while the Bivalves showed an approximation to present conditions. A great majority of the Lower Tertiary (Eocene and Oligocene) genera still exist, but none of the species. During the succeeding Miocene a few species, which are still in existence, made their appearance, while of the Pliocene species 80 or 90 per cent. are represented in the recent fauna.

"At the close of the Eocene the wide distribution of many types now characteristic of warm, temperate, or tropical waters, began to be restricted, and during the Miocene the faunal boundaries of the Mollusca were mapped out nearly on existing lines. This was more true of the non-marine forms; but not till the Pliocene did each geographical province come to assume its present distinctive features." (p. 50.)

Space does not admit of a more extended notice of this interesting volume, which gives us in a few concise pages an accurate summary of living and extinct Mollusca. There is an excellent index, but we would suggest in the next edition a glossary for the unlearned reader's use. A diagram of a Gastropod and a Pelecypod shell would be more useful to the reader in the text of the chapter on Classification to show the topography of the shell, although well illustrated on pl. vi and other plates at the end of the volume. The book needs only to be known in order to be appreciated and widely circulated. We commend it to all students of the Mollusca; those who are not will by reading it no doubt become so.

II.—British *Pisidia*.

Catalogue of the British Species of *Pisidium* (Recent and Fossil) in the Collections of the British Museum (Natural History), with notes on those of Western Europe. By B. B. Woodward, F.L.S., etc. 8vo; pp. x, 144, with 30 plates. London: printed by order of the Trustees of the British Museum, 1913. Dulau & Co., Ltd., 37 Soho Square, W. Price 10*s.* 6*d.*

Of all the groups of British freshwater shells the *Pisidia* have hitherto been the most puzzling. No two authorities have been in agreement and no real test for the species had been noted. It must therefore be a great relief to students to find that at last the golden key has been discovered by B. B. Woodward, who in this monograph shows clearly that the various species can be correctly differentiated by their hinge structures.

Pioneer work of this character is not easy. First it had to be shown that hinge characters were constant; then the various species had to be discriminated and identified with forms previously described on shell form alone; and lastly the whole of the available material had to be examined and compared. The result of all this labour is the volume before us, a volume which will be the foundation of all future work, and everyone who has hitherto vainly tried to identify *Pisidia* is now under a deep debt of gratitude to Mr. Woodward. When we mention that nearly one hundred described species are sunk as synonyms the literary labour alone of the author can be appreciated. Seventeen species are dealt with; fifteen of these are British, one is a living Continental, and one an extinct Pleistocene Belgian form. It is noteworthy how the species have existed unchanged in the British Islands for a very long period. One form ranges from the Coralline Crag (Pliocene) of Suffolk to the present day; four living species are known from Norwich Crag (Pliocene) times, and five recent species make their first appearance in the Cromerian (Forest Bed) of West Runton, Norfolk, whilst one species ranges from the Norwich Crag to the Pleistocene of Crayford.

Environment plays a considerable part in the variation of shell form, and the differences between river forms and lake forms are fully dealt with. Non-recognition of this non-significant variation has in the past been the cause of the multiplication of species.

An excellent feature in the volume is the series of typomaps, thus enabling the reader to ascertain at a glance the exact range of any species on these Islands. The plates are perhaps a little lacking in clearness of definition, and as the original photos were undoubtedly sharp this must be due to the difficulty of printing in numbers. Mr. F. W. Reader deserves praise for his share in this difficult work.

There are a few unimportant errors which we have noticed. Thus, on p. 36 "Pleistocene of Uxbridge" is a slip for "Holocene of Uxbridge", and on pp. 43 and 78 Cappagh is in Waterford, not Limerick. The credit for the first discovery of *P. supinum* is here given to Dr. A. C. Johansen in 1901, but it was recorded from Scotland in 1880 by Sandberger.

This volume begins a new era in the publications of the British Museum, since it deals with specimens preserved in the Geological and Zoological Departments, and the old artificial barrier of "fossil and recent" has disappeared, we hope, for ever.

III.—Text-Book of Palæontology. Edited by Charles R. Eastman, Ph.D. Adapted from the German of Karl A. von Zittel. 2nd edition, revised and enlarged. Vol. I. 8vo; pp. xii, 840, with about 1,600 illustrations. London: Macmillan & Co., Ltd., 1913. Price 25*s*. net.

NEARLY fourteen years have gone by since the appearance of the first English edition of von Zittel's Textbook, and in the notice of it in the Geological Magazine for 1900 (p. 232) attention was drawn to the fact that Dr. Eastman, the translator and editor, had enlisted the assistance of a number of specialists in the principal groups of fossil Invertebrata to act as collaborators with him in bringing out the work. This plan proved so successful that it has again been adopted by the editor in the preparation of this new edition, and at the beginning of the volume he has given a list of seventeen coadjutors and of the particular group or groups of fossils which they have respectively treated. By their efforts the editor states that many parts of the work have been entirely rewritten, others have been amended, re-arranged, and enlarged, and the classification in various places has been considerably altered.

It would exceed our limits to comment on these emendations, but we may just note the rectification of a very conspicuous error in the first edition—that of placing some species of the genus *Monticulipora* with the Tabulate Corals and others with the Bryozoa. The true relationship of the supposed corals is to the Bryozoa, and in the present edition they are rightly placed in this class with their allies.

The principal new fossil forms of Invertebrata discovered since 1900 are included in the present volume, and many of them figured. In this connexion may be mentioned the strange new forms of Medusæ, Chætopods, Holothurians, etc., discovered by Dr. C. D. Walcott in the Middle Cambrian rocks of British Columbia.

Another special feature of the work is the bibliography of the respective groups, which is brought down to recent dates; it also includes references to the more important literature of the recent as well as the fossil forms.

No other work in the English language furnishes us with so complete a description of fossil Invertebrata as the present textbook, and it can be heartily recommended to all interested in the study of palæontology.

IV.—Geological Survey of Scotland.

The Geology of the Fannich Mountains and the country around Upper Loch Maree and Strath Broom. By Dr. B. N. Peach, F.R.S., Dr. J. Horne, F.R.S., the late W. Gunn, C. T. Clough, M.A., and E. Greenly; with contributions by L. W. Hinxman, B.A., T. I. Pocock, M.A., and C. B. Crampton, M.B., and Petrological Notes by Dr. J. J. H. Teall, F.R.S. 8vo; pp. viii, 127, with 8 text-illustrations and 6 plates. Edinburgh: printed for His Majesty's Stationery Office, 1913. Price 2*s.* 6*d.*

THE region described is one of mountains and lochs, with a little of the open sea of Gruinard Bay on the north-west. Deer forests occupy most of the land, the only cultivated areas being along the sea-coast, the lower parts of Straths Beg and Broom, and at the mouth of Kinlochewe River. The more familiar tracts are those along Loch Maree, the portion included being about 9 miles in length, with the Loch Maree Hotel at Talladale and Letterewe on the opposite coast to the E.N.E.

The geological features are clearly shown on the colour-printed map, Sheet 92 (price 2*s.* 6*d.* net). On the west are large tracts of Lewisian Gneiss and Torridon Sandstone, overlain towards the east by unconformable Cambrian rocks. It is pointed out that "the present outlines of the Lewisian Gneiss are, to a considerable extent, a renewal of the pre-Torridonian land surface, which can be shown to have been one of high relief". Thus the Torridonian mountain of Slioch, which attains an elevation of 3,217 feet, comprises nearly horizontal beds of sandstone, which "are seen to envelop three prominent hills of Lewisian Gneiss—one over 2,000 feet in height—with intervening valleys". Some parts of the area may be a restoration of the pre-Triassic land-surface. Rocks of Triassic and Liassic age occur over a small tract on the borders of Gruinard Bay. As at Applecross, they are faulted against the Torridon Sandstone, and the local downthrow is estimated at about 1,000 feet. From Little Loch Broom southwards the Torridon Sandstone forms a fine series of terraced escarpments with corries, as at An Teallach (shown on plate vi), where there are five peaks more than 3,000 feet in altitude. Cambrian quartzites form a prominent escarpment along the eastern exposed area of Torridon Sandstone, and then the ground is greatly disturbed by thrusts and disruptions; a belt of complication due to post-Cambrian movements crossing the area from Loch Broom on the north to the head of Loch Maree and beyond on the south.

The eastern half of the area bordering this region of great disturbance is formed mainly of the Eastern Schists or Moine Series. It "forms part of the Highland plateau, running along the main watershed of the country, which has been deeply trenched by river systems developed since Eocene times". Here is found "some of the wildest scenery in Central Ross-shire". Flaggy siliceous schists and massive muscovite-biotite-gneiss form lofty escarpments and precipitous corries, as exhibited in Fannich Forest (plates i, iv, and v). The Fannich Mountains, which rise to the north of Loch Fannich, include eleven peaks more than 3,000 feet in height, while Beinn Dearg to the north-east rises to 3,547 feet.

Particular accounts are given of all these formations, their subdivisions, and of the various intrusive rocks. The fossils of the Cambrian and Lias are duly noted, those of the latter belonging to the Lower Lias. There are interesting descriptions of the glacial phenomena and of the successive phases of the glaciation; and much attention is devoted to the physical features, to the rivers, and to the modification of former drainage systems, especially during the Glacial Period. The influence is pointed out of faults and great displacements on the trend of the lochs and of some of the ravines, and it is remarked that "Of the larger lakes in the area under consideration, some occupy rock-basins and some are due to the irregular distribution of the glacial deposits".

Raised Beaches, Alluvium, Peat, and Blown Sand are noticed, and in a final chapter on Economic Geology an account is given of the iron-smelting formerly carried on along the shores of Loch Maree and the neighbourhood. The only local ore is that of bog-iron, but in later times ores not found in the district were imported. Limestones (Lewisian, Cambrian, and Lias) have been quarried for lime-burning, etc., and various rocks have been used for building purposes and road-metal. Metalliferous veins are rare, and apparently of no importance: they include ores of lead and copper, and traces of gold. Notes on plantations and on the rainfall are included, and there is a useful bibliography.

V.—Contributions to the Geology of the Nordingrå Region. By José M. Sobral. 8vo; pp. 117, with 12 plates, 1 map, and 1 figure in the text. Upsala: Almqvist & Wiksells, 1913.

THE district included by the author under the title of the Nordingrå Region is situated on the east coast of Sweden, extending from Hernön on the south to Mälmon on the north. Inland, and to the north and south of the district, is a large area of Archæan rocks, but the greater part of the region is occupied by a group of igneous rocks—granites, monzonites, gabbros, and anorthosites. These rocks are overlain by arkose and quartzitic sandstones, belonging to the Jotnian formation of Fenno-Scandia, which are themselves intruded and covered by diabase of pre-Cambrian age. The granites and gabbros are clearly pre-Jotnian, and are believed to be post-Jatulian in age. The field relations of the rocks of the various districts are described in detail, and special attention is devoted to the petrography and petrology of the igneous rocks.

On the east of Ramstäfjarden there is a narrow outcrop of igneous rocks, including pyroxene- and biotite-granites, apparently forming a group distinct from the main granite masses of Nordingrå which are largely hornblende-granites. In the Sub-Jotnian igneous rocks of the mainland the order of solidification appears to have been anorthosite, gabbro, granite. There is interesting evidence of assimilation at the contacts of the granite both with the anorthosites and gabbros and with the Archæan leptites. Monzonitic rocks occur in this area, but the discussion of their relations to the gabbros and granites is reserved for a future publication, which will contain analyses. One development of anorthosite in Nordingrå is remarkable for the abundance of apatite which it contains.

A very striking feature of the petrographical work is the care with which the optical constants of many of the minerals have been determined. The most interesting result of this work is the proof of the occurrence of *fayalite* in many granitic and monzonitic rocks of the region. This mineral appears to occur in several of the typical granites, but it is noticeable that it becomes most prominent in those rocks which are regarded as products of assimilation of gabbro or anorthosite by the granites. The significance of its occurrence cannot be discussed until the rocks have been analysed.

In the two islands of Ulfön there is a large development of granite intruded by diabase with associated acid and basic dykes. The acid dykes are in part contemporaneous with and in part younger than the diabase: they consist of albitites and albite-pegmatites. One of these has been made the type of a new rock name, Värnsingite: it is a coarse-grained rock consisting mainly of albite with some augite, magnetite, and titanite, and is regarded as a 'diabase-pegmatite'. The basalt dykes are the youngest rocks in the district. They show an abnormal development of plagioclase phenocrysts in a narrow zone at their contact with the diabase or granite. This is attributed to inoculation of the intruding magma, when in the metastable state, by the plagioclase of the country rock.

Monzonitic rocks occur in this region and range from rather acid varieties to rocks allied to kentallenites, but containing olivine rich in iron. From a study of the field relations of these rocks the author is led to the conclusion that they are derived by assimilation of granite by the diabase. If this be the case it forms a very important example of the assimilation of an acid by a more basic rock, and, further, it shows that 'hybrid' rocks are not necessarily of very unusual composition. Pending the publication of more analyses these conclusions will possibly be received with some hesitation. Two analyses of kentallenites are given and one of a fayalite-monzonite. The field relations of these occurrences are not conclusive, and the occurrence of fayalite at once suggests comparison with the monzonitic rocks of the mainland; this point will doubtless be settled by the author in his further publications. At Svartbergsviken is an inclusion-like occurrence of monzonitic rocks, grading from adamellite at the centre, through banatites and monzonites, to a variety of the Ulfö diabase, and here the field evidence of assimilation is more convincing. Two analyses of the 'hybrid' rocks are given, together with analyses of the diabase, but still more analyses are needed to strengthen the case. There appears to be no close connexion between the composition of the rocks of this occurrence and the kentallenites and fayalite-monzonites mentioned above, and in criticizing the conclusions of the author the two groups must be considered apart.

Petrologists will await further contributions on these rocks with great interest, for none can fail to appreciate the real excellence of the present work. W. C. S.

VI.—Canada Department of Mines. Geological Survey. Victoria Memorial Museum. Bulletin No. 1. 8vo; pp. 200, of which 13 are printed as plates. Ottawa, October 23 [i.e. November 21], 1913.

The papers in this new publication are distributed under the headings Palæontology, Palæobotany (thus showing that by Palæontology is meant Palæozoology), Mineralogy, Natural History (which appears intended to include both recent Botany and recent Zoology), and Anthropology (which from the title of the only paper under this heading appears to include Archæology). The Geological Survey of Canada is thus continuing the traditions of the time when it was known as the Geological and Natural History Survey of Canada. There is no heading Geology, for it is doubtless intended that papers dealing with that subject will continue to be published as heretofore in the direct Reports of the Survey. The majority of the papers in the present number have, however, a geological bearing.

The first paper is a redescription of the type-specimen of *Ottawacrinus typus*, W. R. Billings, by Dr. F. A. Bather, who considers that all the radials of this form are transversely bisected, and finds it difficult to draw any clear distinction between the upper halves of such radioles and the proximal brachials. In the following "Note on *Merocrinus*" Dr. Bather applies this view to that genus also. Mr. L. M. Lambe records the occurrence of Helodont teeth in beds believed to be of Upper Devonian age in Alberta. Dr. P. E. Raymond publishes "Notes on *Cyclocystoides*", in which he suggests that this curious fossil may be the highly specialized root of a free crinoid, "a sort of sucker-disk." "It is even possible," he says, "to think of this disk as a swimming organ." Dr. Raymond also has two papers on Trilobites, in one of which he describes a new species of *Holasaphus* and in the other some new species of Asaphidæ. The same author describes two new species of *Tetradium*, one of which is from the Lowville Beds of Ontario, but the locality and horizon of the other are not stated—a probably quite unintentional omission. Returning to the Trilobites, Dr. Raymond revises the species that have been referred to the genus *Bathyurus* and erects for some of them the new genera *Petigurus* [*sic*], *Hystricurus*, *Haploconus*, *Platycolpus*, *Plethopeltis*, *Goniurus*, and *Leiostegium*. Miss A. E. Wilson then founds a new genus of Brachiopod, *Oxoplecia*, for a species *O. calhouni*, from the base of the Utica.

The two papers under Palæobotany are by Mr. W. J. Wilson, who describes *Lebephyllum*, a new genus of Dicotyledonous plant from the Tertiary beds of Kettle River, B.C. This is based on leaves of uncertain affinity, but the name in any case should have been *Lebetophyllum*. He also describes a new species of *Lepidostrobus* from the Minto Coal-mines.

Under Mineralogy Mr. R. A. A. Johnston discusses an occurrence of Prehnite at Adams Sound, Admiralty Inlet, Baffin Island.

If this Bulletin is intended for the prompt publication of short papers it may prove very useful, but we observe that the MS. of the first two papers was transmitted in July, 1910, so, at any rate, that is not an example of promptitude.

VII.—Maryland Geological Survey.

UNDER the direction of the State Geologist, Dr. William Bullock Clark, two handsome volumes of letterpress and one of plates, on the Devonian System of Maryland, have been issued (1913). They form vols. v to vii of the series of reports dealing with the systematic geology and palæontology of the State.

Vol. V, Lower Devonian (pp. 560, with 17 text-figures and 16 plates, also 82 of fossils in atlas), opens with an instructive and interesting Introduction on the General Relations and the Paleography of the Devonian, with an Historical Review and Bibliography, by Drs. C. K. Swartz and C. Schuchert, and Professor C. S. Prosser. Attention is first drawn to the original labours of Sedgwick and Murchison, aided by Lonsdale, in the foundation of the Devonian System, but, as justly remarked, the limits of the system "were not clearly defined", and indeed with regard to the Silurian junction no evidence was to be found in Devonshire. Owing to the folded and faulted structure of the English area, the true succession of the subdivisions and their respective faunas could not be distinguished, but subsequent researches of many geologists in the Rhine Valley, in Belgium, the Ardennes, the Hartz Mountains, and in Bohemia have established the sequence on a firm basis, and it has become "the type of the Devonian System of the world".

The authors point out that the Devonian of Eastern America was first critically studied by James Hall, aided by de Verneuil, when they included the strata from the Catskill down to the Oriskany Sandstone as Devonian; while at a much later period Kayser demonstrated the Lower Devonian age of the Helderberg (Lower Helderberg of Hall), and this conclusion has been more fully confirmed by Drs. J. M. Clarke and C. Schuchert.

In a map showing the distribution of the Devonian in Maryland, and in a table in the text, the following subdivisions are recognized:—

Upper	Catskill red sandstone Formation.	
	Jennings Formation	Chemung Sandstone.
		Parkhead Sandstone.
		Woodmont Shale.
		Genesee black shale.
Middle .	Romney Shale . .	Hamilton Shale.
		Marcellus black shale.
		Onondaga Shale.
Lower	Oriskany Sandstone	Ridgely Sandstone.
		Shriver Chert.
	Helderberg Limestone	Becraft member.
		New Scotland member.
		Coeymans member.
		Keyser member.

The following statements contain so much of general interest that it appears desirable to quote them at some length:—

"The Devonian of Maryland forms a part of the Appalachian Province which extends from New York southward in the Appalachian Mountains and Plateau. The resemblance of the formations to those of the northern part of the area is so close as to establish their essential identity both in lithology and fauna, and hence the similarity of the conditions under which they were deposited, the chief difference being the development of the Keyser Limestone in Maryland, an earlier phase of the Helderberg than has hitherto been recognized in New York, and the profusion of life in the Oriskany. In Lower Devonian time the Helderberg and Oriskany seas stretched southward from New York to beyond Maryland. The Middle Devonian was ushered in by a slight deepening of the seas in Maryland, clays being deposited near the shore in Onondaga time, while limestone was formed in the open sea farther west. . . . The Upper Devonian introduces one of the most interesting chapters of the history of this period. At the beginning of Upper Devonian time a fauna appears comprising few species, one of which, *Hypothyris cuboides*, is found at such widely separated points as New York, North-Western America, the Rhine Province, Russia, and China. It seems, therefore, to have encircled the northern hemisphere in its journeys. The cuboides fauna lasted but a short time. In later Middle Devonian time the sea had deepened throughout the west in North America. The descendants of the Middle Devonian shore-loving Brachiopods of the eastern area continued to live in the shallower waters, where they received new species from the Atlantic, and by their combination formed the Ithaca fauna. The deeper waters off shore were invaded by forms that differed greatly from all that preceded them in this region. They consist chiefly of Goniatites (Cephalopods with angular sutures) and minute Pelecypods. The rarity of Brachiopods is conspicuous. This assemblage, termed by [J. M.] Clarke the Naples fauna (also known as the Intumescens fauna from its guide species, *Manticoceras intumescens*), is believed by him to have journeyed from its home in north-eastern Arctic Russia via north-western America to New York and eastward to the Rhine Valley, where it is found in a similar position, its route being indicated by the progressive development of the species. . . . As the level of the sea oscillated, leading to the interleaving of the two types of containing sediments in central New York, the Naples and Ithaca faunas migrated back and forth. That these faunas ranged southward into Maryland is shown by the occurrence of the Naples fauna in abundance in the Genesee and lower beds of the Woodmont member of the Jennings formation of the western sections and the replacement of the Naples fauna by the Ithaca fauna in the upper beds of the Woodmont member of the eastern sections, while it still continued to live in the west, indicating conditions essentially similar to those that existed in New York at this time. It results that three independent faunas coexisted in this province in early Upper Devonian time, their range being determined by the physical conditions under which they dwelt, while they migrated back and forth as these conditions varied."

Other instances of the introduction, survival, and recurrence of species are discussed; and it is pointed out that towards the close of the Devonian period the land was elevated, and the thick deposits of red clays and sands of the Catskill formation were accumulated in lakes and embayments. The strata contain macerated remains of plants and fragments of fishes. "The Devonian was finally terminated by a subsidence of the continent, and a new invasion of the Mississippi seas introducing Lower Carboniferous time."

The Paleography of the Devonian is illustrated by a series of maps. The bulk of the volume comprises the details of the stratigraphy of the Lower Devonian rocks, and of the range and distribution of the fossils: this part is by Drs. Schuchert, Swartz, T. Poole Maynard, and R. B. Rowe. The systematic paleontology is by Drs. Schuchert, Swartz, Maynard, D. W. Ohern, E. O. Ulrich, and R. S. Bassler.

Vol. VI, Middle and Upper Devonian (pp. 720, with 2 text-figures, 6 plates, also 38 of Middle Devonian and 29 of Upper Devonian fossils in atlas). In this volume we have full particulars of the strata, of the correlation of subdivisions, the distribution and range of species, and the relations of the faunas to the sediments. The general stratigraphic and paleontologic work is by Professor Prosser, Dr. E. M. Kindle, and Dr. Swartz; the systematic paleontology of the Middle Devonian is mainly by Professor Prosser and Dr. Kindle, with contributions on Bryozoa and Ostracoda by Dr. E. O. Ulrich and Dr. R. S. Bassler; and the systematic paleontology of the Upper Devonian is by Dr. J. M. Clarke and Dr. Swartz.

The illustrations in the two volumes of text comprise effective views of formations and scenery, and a series of columnar sections. Vol. VII consists of the *Atlas of Plates*, 149 in number. Many new species are figured, while among European forms we note *Hindia sphæroidalis*, Dunc., *Favosites basalticus*, Goldf., *Halysites catenulatus*, Linn., from the Lower Devonian; *Atrypa reticularis*, Linn., from Lower, Middle, and Upper Devonian; and *Schizophoria* (*Orthis*) *striatula*, Schloth., *Spirifer disjunctus*, Sow., and *Buchiola* (*Cardiola*) *retrostriata*, v. Buch, from the Upper Devonian.

H. B. W.

VIII.—Bulletins issued by the United States Geological Survey.

Bulletin 521. The Commercial Marbles of Western Vermont. By T. Nelson Dall. pp. 170, with 17 plates (including 2 maps) and 25 figures in the text. 1912.—There is already an extensive literature on the geology of the 'marble belt' of Western Vermont, and the present bulletin is designed to summarize the previous work, providing those interested in the marble industry with a clear idea of the geological structure of the district and of the microscopic structures of the various marbles. In describing the relations of the calcite to the dolomite in the area, the author points out that repeated alternations of calcite and dolomite bands are frequent: this can only be explained by assuming repeated changes in the conditions of sedimentation to have taken place. The mineral constituents and microstructure of the marbles are described, and are illustrated by numerous text-figures, and a clear account is given of the geological structure of the area. There is a useful glossary of technical terms and a good index.

Bulletin 522. Portland Cement Materials and Industry in the United States. By Edwin C. Eckel, with contributions by F. Burchard and others. pp. 401, with 19 maps and 2 diagrams. 1913.

Parts i and ii of this report describe the chemical and physical properties of Portland cement materials, but the greater part of the book deals with the cement resources of individual States. This involves a description of the main occurrences of limestone, chalk, and shell-marl in the United States. It is shown that the value of the raw materials depends on their location with respect to fuel, transportation routes and markets, and, accordingly, these points are considered in each case. The distribution of the materials is illustrated by geological maps wherever possible. Short bibliographies are given under the several States, and there is a good general bibliography, which has been compiled by F. Burchard.

Bulletin 527. Ore Deposits of the Helena Mining Region, Montana. By Adolph Knopf. pp. 143, with 7 plates (including 2 maps) and 4 figures in the text. 1913.—The detailed description of the mining districts of the Helena region, which occupies the greater part of this bulletin, is preceded by a clear sketch of the geology of the region as a whole. The ore-deposits are silver-lead and gold-silver deposits, and they belong to two distinct periods of ore-deposition, following two periods of marked igneous activity in the area. The older group of lodes and veins followed the intrusion in late Cretaceous time of a great mass of quartz-monzonite forming the northern extension of the Boulder batholith. These are all tourmaline-bearing lodes, the ore consisting principally of galena associated with sphalerite and pyrite. This appears to be the first recorded occurrence of silver-lead ores associated with tourmaline. Analyses and field evidence show that the tourmaline and the sulphides travelled together: they were probably derived from the quartz-monzonite magma, but the introduction of the ore took place distinctly later than the intrusion of the quartz-monzonite and of its associated aplites. The second period of ore-deposition followed the extrusion of a group of dacites of Upper Miocene age, and of a group of rhyolites, probably slightly younger than the dacites. The ores of this period are found in fissure veins, characterized by the presence of cryptocrystalline quartz with a subordinate quantity of sulphides. They are worked for their gold and silver contents. These are low-temperature ore-deposits, while the older group, characterized by tourmaline, were deposited at a *relatively* high temperature. Numerous analyses are given of samples taken from veins of both groups occurring in quartz-monzonite, and interesting comparisons are made between the metasomatic processes which operated during the two periods of mineralization.

Bulletin 529. The Enrichment of Sulphide Ores. By W. Harvey Emmons. pp. 260. 1913.—The theory of enrichment of sulphide ores, first put forward in 1900, has been found to have very wide application, and has proved to be of considerable value in the development of sulphide deposits. It is a theory which lends itself especially to research in the laboratory, and though much work has been done, there are many problems which still remain unsolved. This bulletin summarizes our present knowledge of the subject; it supplies some new material and suggests lines for further inquiry. The bearings of physical conditions on the enrichment of deposits are discussed. The chemistry of enrichment is considered: firstly in the light of experimental data; secondly from considerations of the composition of mine waters, thirty-seven samples having been analysed. Very valuable are the contributions on the chemical relations and occurrence of the minerals of copper, silver, gold, lead, zinc, and iron, and of certain gangue minerals, including felspars, kaolin, sericite, alunite, sulphates, and carbonates. There is a brief review of the several classes of sulphide deposits in the States, and a detailed review of the various mining districts. While having very important bearing on the economic side of mining geology, the bulletin forms a valuable contribution to the mineralogical chemistry of the sulphide minerals.

IX.—Probable Origin of the African Elephant.

W. O. Dietrich.—Zur Stammesgeschichte des afrikanischen Elephanten. Zeitsch. f. induktive Abstammungs- und Vererbungslehre, vol. x, p. 49, with 7 text-figures, 1913.

IN this paper the author discusses the probable origin of the African Elephant. He first points out how very little material there is at present upon which to base an opinion, and gives a useful list of the principal discoveries. He then discusses at some length the chief dental characters which are of importance in determining relationships within the group. From the nature of its tooth structure he concludes that the African Elephant, while in some respects highly specialized, is an archaic type, and expresses his belief that its primitive characters cannot be the result of retrogressive changes in a more advanced type such as *Elephas antiquus*, but on the other hand prove an independent descent from some at present unknown type of Mastodon. It is important to note, however, that although a Mastodon has been recorded from South Africa, all the true elephants at present known from deposits of Pliocene or Pleistocene age in Africa (the Sudan, Zululand, and recently British East Africa) possess teeth of a more specialized type than those of *E. africanus*. It seems, therefore, by no means certain that this species may not have acquired the peculiar characters of its dentition as a result of retrogressive changes, possibly in consequence of some peculiarity in its food.

A table is given, showing at a glance the various views that have been expressed on this subject.

C. W. A.

X.—Brief Notices.

1. Wisconsin Geological and Natural History Survey.—An instructive work on "The Geography and Industries of Wisconsin", by Professor R. H. Whitbeck, has been issued by this survey (Bulletin No. xxvi, Educational Series, No. 3, 1913). The mineral industries include, in order of importance, iron-ore, zinc-ore, stone, clay, mineral water, lime, sand, and lead-ore. The annual output is valued at about twenty million dollars. No coal occurs, the bed-rocks being all older than any coal-bearing formations. In the value of commercial mineral waters Wisconsin is foremost among the States. More

than six million gallons from the mineral springs of Waukesha are sold annually. More important, however, are the other sources of wealth. The forest industries are stated to have yielded "far more wealth than the gold-mines of California"; in agricultural industries Wisconsin ranks about tenth in States for the annual value of farm products: the soils due mostly to glacial drifts are generally fertile, while the manufacturing industries include lumber, metal-work, farm produce, leather, etc. The work is illustrated by maps, diagrams, and photographic views of mine-works, quarries, forest, and logging scenes, soil formation, farm and fruit lands, etc.

2. Mount Lyell Copper District of Tasmania.—On this subject an important article has been published by Messrs. C. G. Gilbert and J. E. Pogue (Proc. U.S. Nat. Mus., vol. xlv, No. 2005, p. 609, 1913). The authors deal with the Mount Lyell and North Mount Lyell Mines: the former yields chalcopyrite, etc.; the latter yields bornite predominantly, with chalcocite, also tetrahedrite and chalcopyrite. The history and geology of the area receive due attention, and the authors discuss the paragenesis and secondary enrichment of the ore-deposits.

REPORTS AND PROCEEDINGS.

Geological Society of London.

December 17, 1913.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

At the conclusion of a paper entitled a "Supplementary Note on the Discovery of a Palæolithic Human Skull and Mandible at Piltdown (Sussex)", by Charles Dawson, F.S.A., F.G.S., and Arthur Smith Woodward, LL.D., F.R.S., Sec.G.S., an Appendix by Professor Grafton Elliot Smith, M.A., M.D., V.P.R.S., was inadvertently omitted from the report published last month (see pp. 44–5). Professor Elliot Smith pointed out that the presence of the anterior extremity of the sagittal suture, which hitherto had escaped attention, had enabled him to identify a ridge upon the cranial aspect of the frontal bone as the metopic crest, and thus to determine beyond all question the true median plane. It is 21 mm. from the point of the large fragment (in the frontal region). Mr. F. O. Barlow called his attention to the fact that the contour of the frontal bone when viewed in norma facialis confirms this identification of the median plane, because the summit of the curve is directly above the endocranial metopic crest. Professor J. T. Wilson pointed out to him that the direction of the orbital plate of the frontal bone is such that it assumes its proper position only when the fragment is so placed that the above-mentioned crest is in the median plane. The backward prolongation of the frontal median crests cuts the parietal fragment precisely along the line determined by Dr. Smith Woodward on other grounds. It indicates that the posterior part of the sagittal suture is obliterated—a view that is confirmed by the presence of an irregular wavy furrow upon the bone, precisely similar to that found in other skulls where this suture had recently closed. This may occur in modern man at any time between about 30 and 40 years of age. The evidence afforded by the parasagittal ridge on the left parietal, by the meningeal grooves, and by the positions occupied by the fragments of the lambdoid suture upon the occipital and parietal fragments, corroborates the correctness of this identification of the median plane.

CORRESPONDENCE.

THE FREEZING OF SURFACE SOIL.

Sir,—In *Nature* for 1911 I described the occurrence of tooth-like projections of fibrous ice which formed on exposed pieces of chalk partly buried in the soil. Here the water had not frozen *in* the chalk but *on* the surface, fresh supplies of water coming from below through the capillaries of the stone to freeze at the surface. Each pore would seem to have produced a separate crystal fibre, the fibres from each pore adhering to one another and resembling fibrous gypsum in appearance. Occasionally when the supply of water from below varied over the chalk surface, strains were set up by the irregular growth of the 'ice-teeth', which caused the mass to split along the fibres and grow in spiral forms. The amount of ice produced was several times greater than the volume of the chalk upon which it formed, showing that the water had passed from the wet ground through the chalk and frozen on the surface.

Since describing the above I have seen a "Note on the action of Frost on Soil", by Milner Roberts, in the *Journal of Geology*, vol. xi, pp. 314–17. He says, "The action of frost in altering the surface of the soil was well shown during the period of cold weather which prevailed over the Puget Sound district from February 10 to 18, 1903.

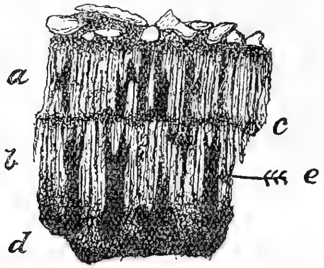
"The first night's frost had its usual effect of raising the surface of loose ground, which was well illustrated by gravelly soil. A layer of ice consisting of vertical prisms five-eighths of an inch long formed during the night at a depth of about five-eighths of an inch below the surface, thus raising the overlying material without otherwise disturbing it. The cold of the following night produced a similar layer of ice almost an inch thick below the first one, raising the latter along with its load of sand and gravel.

"The following conditions prevailed and seem to have controlled the formation of these many storied forms: (1) ground which was not frozen and which was readily permeable to moisture; (2) freezing temperature at night; (3) mild thawing in the daytime; and (4) considerable moisture in the soil."

During the present week similar conditions have prevailed here, and similar effects have been produced on a gravel walk. In the Figure, p. 96, which is full size, *a* and *b* are two layers of fibrous ice resting upon wet clayey soil *d*. During the first night's frost the pebbles and some soil were lifted. On the following night the layer of ice *b* was formed. It, however, raised with it a thin layer of soil *c*. Particles of soil were scattered throughout the ice, having been detached from the soil below and lifted by the growing ice fibres.

This growth of ice was not regular over the whole surface, for here and there pits and grooves were left in the gravelly surface. Examination also showed that there were numerous cavities *e* in the fibrous ice layers, resulting from the local failure of the water supply from below.

The segregation of the water to form ice layers when the surface of the ground freezes not only seems to have a bearing upon the question of the flow of the frozen soil-cap downhill, but also serves to explain the peculiar arrangement of the stones at or near the surface, especially in high latitudes. It has been remarked by many that in frigid climates the stones and other objects on the ground stand with their longer axes in a vertical position.



During the melting of the ice layers below the surface stones would subside irregularly, slipping on end into the cavities and channels formed by the melting of the ice below. When it is remembered that the formation of ice layers beneath the surface and their melting must take place very frequently in high latitudes, the positions of the stones near the surface must be moved with regard to each other very often. In this movement we have a cause which appears to be capable of producing the peculiar vertical arrangement of the stones near the surface.

Such a vertical arrangement of the longer axes of the stones may be seen in the upper surfaces of many of the high-level river gravel terraces of England, but not in the lower gravels. It is common in the high-level river gravel terraces of the Trent, where signs of disturbance often extend downwards many feet from the surface.

R. M. Deeley.

MISCELLANEOUS.

Munificent Bequests in aid of Science.—Dr. Tempest Anderson, who died on board ship in the Red Sea on August 26 last year, has left £50,000 to the Yorkshire Philosophical Society, of which he was formerly president; and £25,000 to the Percy Sladen Memorial Fund, established by his sister, Mrs. Sladen, in 1904.

Geological Survey.—The President of the Board of Education has promoted Mr. G. W. Lamplugh, F.R.S., to the post of Assistant Director (for England and Wales) on the Geological Survey of Great Britain, and Mr. T. C. Cantrill to that of District Geologist. The appointments took effect on January 6, 1914.

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CONTENTS.

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Horace B. Woodward

1848—1914.

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

No. III.—MARCH, 1914.

ORIGINAL ARTICLES.

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

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

(*Continued from Dec. V, Vol. X, p. 438.*)

(PLATE IV.)

Cribrilina cicatricifera, sp. nov. (Pl. IV, Figs. 1, 2.)

Zoarium unilaminate, adherent.

Zoœcia convex, quite separate, very small, average length ·35 to ·38 mm. and width ·2 mm.; numerous radiating imperforate lines are faintly perceptible on some of them in a suitable light, and were doubtless present on all; they are hardly 'furrows', resembling rather superficial cuts; apertures very slightly heel-shaped.

Oœcia abundant, relatively large, globose with a strongly concave free edge.

Avicularia perhaps represented by the tiny bodies like abortive zoœcia, with long, narrow apertures which are scattered freely over the zoarium.

This dwarf form occurs sparingly in the zone of *M. cor-anguinum*, and probably persists in small zoaria up to the Weybourne Chalk.

Cribrilina vulnerata, sp. nov. (Pl. IV, Figs. 3, 4.)

Zoarium unilaminate, adherent.

Zoœcia convex, quite separate, small, average length ·4 to ·42 mm. and width ·3 mm., with a few radiating imperforate lines, resembling (but rather more marked than) those of *C. cicatricifera*, visible on many; apertures markedly horseshoe-shaped, rather variable in size; low down at the upper end a well-marked pore often occurs.

Oœcia very large and globose, with a deeply concave free edge, enveloping the upper part of the aperture; they are very abundant, but very fragile, the specimen shown in Fig. 3 being almost the only one I have seen; the broken edges present an appearance quite distinctive under a pocket magnifier.

Avicularia unknown.

This species is abundant in the Trimingham Chalk and occurs sparingly in the Weybourne Chalk. Comparison with the type of *Cellepora megastoma*, Desm. & Lesueur,[1] might show a relation with that species, the figure of which is quite inadequate.

This and the foregoing species clearly illustrate the last stage before the final consolidation of a Cribrilinid front wall.

[1] Bull. Sci. Philomathiques, 1814, p. 54, pl. ii, fig. 5.

MOLLIA LAMINARIA, sp. nov. (Pl. IV, Figs. 5–7.)

Zoarium unilaminate, adherent, consisting of a thin uneven crust out of which the zoœcia rise more or less disconnectedly.

Zoœcia convex, quite smooth, very small, average length ·3 to ·32 mm., generally in contact with others on one or more sides, but sometimes wholly isolated; they show a distinct tendency to linear arrangement; apertures keyhole-shaped and rather short for that type.

Oœcia very large but inconspicuous, globose with a very short concave free edge which slightly impinges on the zoœcial aperture.

Avicularia perhaps represented by the tiny aborted zoœcia which are scattered freely about the zoarium.

Very abundant at Trimingham and not uncommon in the Weybourne Chalk. I place it temporarily in the genus *Mollia* on account of its apparent relationship to *M. guttata*, d'Orb.[1]

It might be a specimen of this form which was figured as *Flustra utricularis* by Samuel Woodward.[2]

HOMALOSTEGA MARGINULA, sp. nov. (Pl. IV, Figs. 8, 9.)

Zoarium unilaminate, adherent.

Zoœcia of moderate size, average length ·5 mm., with circular side walls bent strongly inwards, which at the foot form a distinct thin rim raised slightly above the smooth, flatly arched front wall, but gradually blend into it towards the head; apertures small and superficially semicircular, but apparently contracting progressively downwards into a narrow crescent; fairly large pores occur somewhat irregularly in the side walls when exposed to view.

Oœcia and *avicularia* unknown.

This species occurs very sparingly in the zone of *M. cor-testudinarium* at Seaford and Dover. It seems to have near relations in the early French Chalk, such as *Reptescharellina oceani*, D'Orb.[3]

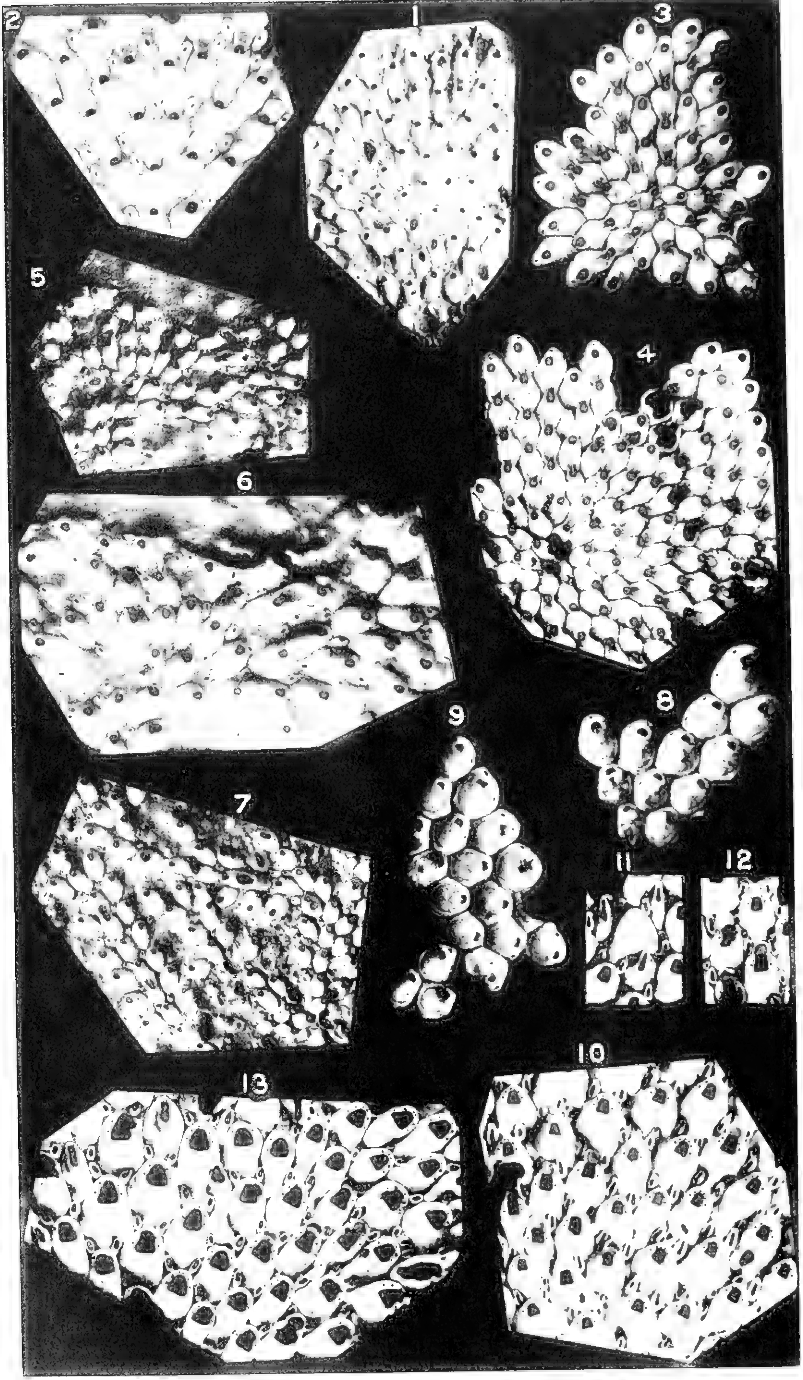
Fig. 8 is given on account of the faint appearance of radiating furrows (? Cribrilinid ancestry) presented by some of the zoœcia.

HOMALOSTEGA NITESCENS, sp. nov. (Pl. IV, Figs. 10–12.)

Zoarium unilaminate, adherent, noticeably bright.

Zoœcia of medium size, average length ·6 to ·65 mm.; front walls flatly arched, slightly below rather sharply defined side walls just below the aperture but rising flush with and merging into them towards the foot; in the upper part of the zoœcium the side walls have a strong tendency to bulge out low down, occasionally producing a sort of external front wall with quite an abrupt margin; apertures small, high, and narrow with a straight lower lip, upwards from which the almost straight sides converge very gradually until they are ended by a very flat arch; paired, circular, flat, wide, perforated spine bases occur on the margin at about half the height, and impinge slightly on the aperture; above them come a pair of pores situate close to the margin just below the upper corners, and another pair occur close together in the centre of the arch.

[1] Pal. Franç. Terr. Crét., tom. v, p. 389, pl. 712, figs. 1, 2.
[2] Geol. Norfolk, by Samuel Woodward, 1833, tab. iv, fig. 7.
[3] Loc. cit., p. 454, pl. 605, figs. 14, 15.



R. M. Brydone, phot. *Bemrose & Sons Ltd., Collo.*

Chalk Polyzoa.

Oœcia fairly abundant but very delicate, the one figured being the only perfect one I have met with, small, and of the water-bottle type, with a globose body, a strongly constricted neck, and a slightly expanded lip; beneath them the margin of the aperture is deeply cut away.

Avicularia small, mandibular, apertures tending to be hourglass-shaped, very numerous, every zoœcium having normally on either side of its head a slightly diverging pair, whose upper ends rest in hollows in the succeeding zoœcium; others are scattered about irregularly, and some of these develop long convex bodies and may become sub-vicarious.

This species, while distinguishable from *Homalostega vespertilio*, Hag., sp.,[1] by the presence of oœcia and the almost rectangular lower corners of the aperture, would be very near it but for the absence in *H. vespertilio* of the apertural spine bases and pores of *H. nitescens.* On making a special examination of some Trimingham specimens of *H. vespertilio* I found to my great interest that practically every zoœcium had faint traces of a similar arrangement of spines or pores. *H. vespertilio* being confined to the Trimingham Chalk and *H. nitescens* to the Weybourne Chalk, it may fairly be supposed that the former is a direct descendant of the latter, but in this respect has not quite completed its differentiation.

HOMALOSTEGA ANTECEDENS, sp. nov. (Pl. IV, Fig. 13.)

This species is so closely allied to *H. nitescens* that it is adequately described by saying that it is slightly larger, more robust, and less angular; its aperture is very much larger in proportion, its small avicularia smaller and its large avicularia larger and even fully vicarious; and its side walls do not tend to bulge out.

It occurs rarely in the (restricted) zone of *A. quadratus*, Hants and Sussex, and I have one specimen from the zone of *O. pilula* (subzone of abundant *O. pilula*) of Sussex.

EXPLANATION OF PLATE IV.

(All figures × 12 diams. unless otherwise stated.)

FIG. 1. *Cribrilina cicatricifera.* Zone of *M. cor-anguinum.* Gravesend.
,, 2. ,, ,, Part of the same specimen. × 21 diams.
,, 3. ,, *vulnerata.* Trimingham. With oœcium.
,, 4. ,, ,, ,,
,, 5. *Mollia laminaria.* Trimingham.
,, 6. ,, ,, Part of same specimen. × 21 diams.
,, 7. ,, ,, Trimingham. Another specimen.
,, 8. *Homalostega marginula.* Zone of *M. cor-testudinarium.* Dover.
,, 9. ,, ,, ,, ,, Seaford.
,, 10. ,, *nitescens.* Weybourne.
,, 11. ,, ,, ,, Another specimen, showing an operculum preserved.
,, 12. ,, ,, ,, Another specimen with oœcium.
,, 13. ,, *antecedens.* Zone of *A. quadratus.* Shawford, Hants.

[1] Marsson, Die Bryo. d. Weiss. Schreibkreide der Inseln Rugen, p. 94, taf. ix, fig. 15.

II.—On Remains of a Gigantic Land Tortoise (*Testudo gymnesicus*, n.sp.) from the Pleistocene of Menorca.

By Dorothea M. A. Bate.

THE receipt of a grant from the Trustees of the Percy Sladen Fund in 1911 made a return to the Balearic Islands possible in the latter part of the same year. Majorca was visited for the third time while a search for Pleistocene ossiferous remains was undertaken for the first time in Menorca and Ibiza, from which no Pleistocene mammalian remains had previously been recorded. No success attended the search in Ibiza. The deposits discovered in Menorca yielded remains of *Myotragus balearicus*, those of a gigantic land tortoise, and of a large *Eliomys*, which proves to be a hitherto undescribed species.

The remains of *Testudo* were obtained from two rock fissures in the Miocene Limestone of the Bajoli Promontory north of Ciudadela, the former capital of Menorca. In one of these it was interesting to find bones of *Myotragus* associated with those of the Chelonian, although the former only occurred at the highest point of the deposit, of which the greater part had been worn and weathered away. This was the only instance in which these two species were found in the same deposit, although several other localities in the island yielded remains of *Myotragus*.

Although small and of a fragmentary character, the collection which forms the subject of this paper includes specimens representing individuals varying greatly in size and indicating a range between the proportions of *T. pardalis* from South Africa to those equalling, if not surpassing, the dimensions attained by the Madagascan *T. grandidieri*.

Remains of gigantic land tortoises have been found very widely distributed both in the Old World and the New, and existed during many geological epochs in much the same form as their representatives of to-day. Discoveries of Pleistocene forms in the Old World have not, however, been very numerous. Deposits in Madagascar have yielded quantities of remains; but in Europe, Malta and Gibraltar seem to have been, until now, the only localities from which examples had been obtained. Those from Gibraltar consist of only two fragmentary specimens, described by Dr. Leith Adams,[1] who also published a description,[2] with figures, of the small collection of *T. robusta* obtained from the cave deposits of Malta by Admiral Spratt.

During the last few years further Chelonian remains have been obtained by Mr. N. Tagliaferro from various rock fissures in Malta. These are now in the Malta University Museum of Natural History, but casts of nine specimens of limb-bones from Corradino have been presented to the British Museum (Natural History). All these are of large size; one especially, an imperfect humerus, indicates an animal of enormous proportions, equalling, or even surpassing, those of *T. elephantina* from Aldabra. In this (B.M. $\frac{R}{3966}$) the circumference

[1] Quart. Journ. Geol. Soc., vol. xxxiii, p. 188, 1877.
[2] Op. cit., p. 177 et seq., pls. v, vi.

of the narrowest part of the shaft is 184 mm., whilst this measurement for the largest Aldabran specimen given by Dr. Günther is 160 mm.[1]

Mr. Tagliaferro is of opinion that his examples indicate the presence of another race, for which he suggested the name of *T. robustissima* in a letter to the *Daily Malta Chronicle* for February 17, 1913. This makes the third species of large land tortoise to be differentiated and described from Malta.

In Chelonians actual size alone is not a very important characteristic. Like those from Malta, the Menorcan specimens show an enormous range in size; one reason to account for this may be the former very great abundance of reptiles in the island. This suggestion is further borne out by the originally large area of the deposits in which the remains were found. The extreme variability, both in actual size and relative measurements, that obtains in the remains of the gigantic tortoises from Mauritius and Rodriguez has already been pointed out by Professor A. C. Haddon.[2]

Owing no doubt to the great reduction made in the numbers of the existing races of gigantic tortoises since their discovery in the Galapagos Group and islands of the Indian Ocean, chiefly on account of the custom of passing vessels taking great quantities on board, it seems to have become a widely accepted axiom that these creatures are too defenceless to exist except in isolated areas where they would not be subject to the attack of other large animals. It seems that this may hold good in the case of civilized and perhaps semi-civilized man, but not with regard to large carnivora, as for instance Mr. Hay writes:[3] "The large Testudinidæ of North America, from the Lower Eocene to the Pliocene, were exposed to the attacks of large carnivora." He continues to say: ". . . Dr. Leidy has figured the claw phalanx[4] of a species of *Testudo* found in Pleistocene deposits in Hardin County, Texas. The individual must have been one of great size. We do not know why some of the Pliocene gigantic tortoises should not have had descendants in the Quaternary worthy of accompanying the great mammals of that period." Further, it may be remembered that although the only remains of large carnivora obtained from the Malta caves was a single indeterminable tooth, Dr. Falconer,[5] in writing to Admiral Spratt, mentioned that "There are numerous bones in your Zebbug cave collection that are *fiercely* gnawed, and evidently by a large predaceous carnivore".

It seems probable that the extinction of a race of giant tortoises would be more easily brought about by the continued and wholesale destruction of the eggs and young, as, for instance, it has been recorded by Mr. Beck[6] that "On Albemarle the dogs and cats undoubtedly eat a great many young tortoises".

The freedom of the adults from attack has also been brought forward as the cause of the thinning of the shell in some of the races

[1] *Gigantic Land Tortoises in the Collection of the British Museum*, London, p. 31, 1877.

[2] Trans. Linn. Soc., ser. II, Zoology, vol. ii, p. 157, 1881.

[3] *The Fossil Turtles of North America*, Washington, p. 373, 1908.

[4] *Contrib. to the Extinct Vert. Fauna W. Territories*, 1873, pl. xxxiii, fig. 21.

[5] Pal. Mem. London, vol. ii, p. 301, 1868.

[6] *Novitates Zoologicæ*, vol. ix, p. 379, 1902.

of the Galapagos Islands, notably in *T. abingdonii*, which "has a carapace almost as thin as paper in most parts".[1] On the other hand, other isolated forms have thick shells, so it seems that some other explanation is required to account for the variation in this respect. Dr. Günther[2] may have been near the truth when he remarked that this character probably was influenced by the nature of their food and was correlated with their mode of progression. The very great and consistent difference in the size of horns carried by a single species, especially among the deer, in different parts of its habitat is well known, and may perhaps be analogous to the varying thickness of shell in the giant tortoises.

It seems necessary to suppose that there have been considerable changes of climate and vegetation since these giant tortoises roamed the island. That Menorca already was an island is indicated by the discovery of remains of a large race of lerot, probably an insular form. At the present day a small species of land tortoise, *T. græca*, is found in Menorca.

It will be seen from the following description of the Menorcan giant tortoise remains that these neither present any very salient points for the differentiation of the species nor indications as to with which form they are most closely related. Therefore it seems advisable to bestow a distinguishing name, at least provisionally on this race, which I therefore propose should be known as *T. gymnesicus*, sp. nov.

It is thought that a brief description of the chief specimens obtained may be of use and interest.

Description of Specimens.

Unfortunately no portion of the skull was recovered and only a single cervical vertebra of moderate size and in a very bad state of preservation.

Carapace.—This is represented by three fragments; one of these is evidently part of a left anterior marginal plate and in shape resembles those of the Madagascan *T. grandidieri*, sloping gently down and having a rounded edge, in marked contrast to some of the earlier Egyptian forms with sharp-edged and abruptly recurved marginal plates. The Menorcan example, which is 17 cm. in length, is slightly convex in outline, and at one end retains part of the line of junction with the next plate. It attains a thickness of 33·5 mm., thus surpassing by some 13 mm. any among a number of fragments from the Maltese caves.[3]

A second Menorcan specimen, still partially embedded in the hard red matrix, is convex in outline and attains a thickness of 27 mm. It is probably part of one of the neural plates, and indicates that there was no great difference in the thickness of the various portions of the carapace, such as obtains in that of some species in which the dorsal area is very much thinner than the periphery.

A third fragment of plate is only 18 mm. thick.

[1] Rothschild, *Novitates Zoologicæ*, vol. iii, p. 85, 1896.
[2] *Gigantic Land Tortoises*, London, p. 24, note, 1877.
[3] Leith Adams, Quart. Journ. Geol. Soc., vol. xxxiii, p. 178, 1877.

Dermal Ossicles.—Two small specimens were obtained from Menorca: one, somewhat ovoid in outline, measures 87 mm. in circumference and about 10 mm. in thickness; it is convex on one side and almost flat on the other. The second example is more irregular in shape; both are highly mineralized, and their bony structure is of much closer texture than is the case in the ossicles of *T. grandidieri*, a number of which are included in the collection of the British Museum (Nat. Hist.). These ossicles occur in *T. perpiniana*, and are found chiefly on the fore-limbs according to the restoration given by Professor Depéret,[1] who lays some stress on their presence, shape, and arrangement, which he cites as among the chief characteristics distinguishing this species from the existing giant races in which they are said to be absent. It may be mentioned that they are present in the gigantic tortoise from the Miocene of Mont Lebèron.

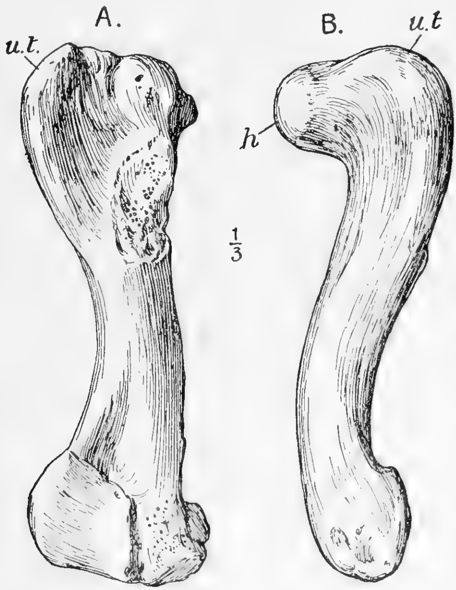


FIG. 1.—Left humerus of *Testudo gymnesicus*. A. ventral surface; B. post-axial surface. *h.* head; *u.t.* ulnar tuberosity. $\frac{1}{3}$ nat. size.

Humerus.—Five specimens of this limb-bone are included in the collection, two belonging to the left and right sides being in a fair state of preservation. These are large and very similar, though they evidently did not belong to a single individual; they are perhaps of more slender proportions than those of *T. grandidieri*. In both the surface of the distal end of the bone is considerably worn and

[1] *Les Animaux Pliocènes du Roussillon* (Mém. Soc. Géol. France), 1890, pp. 150–4, pls. xiv, xv.

damaged. The curvature in these examples is pronounced, but not nearly so marked as in the smaller *T. pyrenaica* or in *T. perpiniana* from the Pliocene deposits of Roussillon.

In the left humerus (Fig. 1) the radial process and the region of the ectepicondylar canal are wanting; the head is prominent, but on comparison was found to be considerably smaller than in a Madagascan specimen, with which, on the other hand, it agrees in the absence of any excavation between the head and the ulnar process. Its greatest length is 21·3 cm. and the smallest part of the shaft is about 10·4 cm. in circumference. In the right humerus the head and ends of the radial and ulnar processes are missing; the circumference of the shaft is 9·3 cm., while the greatest width at the distal extremity is 7·3 cm.

A third example consists of the imperfect distal extremity of the left humerus, which must have been that of an individual of about half the size indicated by the specimens described above. Two fragmentary specimens probably represent portions of the distal extremities of humeri which would have greatly exceeded in size any of the other corresponding bones in the collection. One shows a thickness of 4·4 cm., as compared with 3·5 cm. in the right humerus described above, while the second fragment was probably part of a bone of still greater dimensions. There is no example of this limb-bone in the earlier collection from Malta, but two are included among the casts recently acquired. One of these (B.M. $\frac{R}{3967}$) is of the right side, and is in an almost perfect state of preservation except for the loss of the greater part of the ulnar process. Its greatest length is 23 cm., and the smallest circumference of the shaft is 11·4 cm. and the greatest width of the distal extremity is 8·7 cm. These measurements are only slightly greater than those of the two well-preserved specimens from Menorca. The second specimen is the very large one already referred to.

It may be worth mentioning that in the British Museum (Nat. Hist.) collection there is an isolated specimen of this limb-bone from Madagascar (R 2104) which is truly colossal, and differs as much from the remainder of the collection from that island as it does from the Menorcan examples. Its proportions may be realized from its greatest length, which is 35 cm., the smallest circumference of the shaft 19·1 cm., and the greatest width of the distal extremity 14·4 cm. These measurements indicate a creature surpassing in size any other known Pleistocene form.

Radius.—The collection includes two distal extremities of this limb-bone, neither of very large dimensions. The smaller is of the left side, and, though stouter, in general outline it resembles the smaller of two specimens in the Maltese collection, especially in the angle of the ulnar articulation, which is very different in some other species. Its circumference at the break is about 47 mm., and the greatest thickness of the carpal articulation is 14 mm. The preaxial angle is missing. The second example is of the right side and is broken off a short distance above the ulnar articulation. It has a circumference of 52 mm. at the break and a greatest thickness of hardly more than 18 mm. A very large radius of the right side in

Mr. Tagliaferro's collection has a greatest length of 16·8 cm. and an antero-posterior width of the proximal extremity of 7·3 cm.

Ulna.—This limb-bone is represented in the Menorcan collection by one specimen only. The olecranon is missing, otherwise it is almost entirely preserved, but its outline is somewhat obscured owing to its being still attached on its post-axial aspect to the hard red matrix.

It is of the right side, and is 85 mm. in length from the highest point of the humeral articulation. The pre-axial surface of the bone is slightly damaged, but it is evident that there can have been only the slightest, if any, roughening for the distal articulation with the radius. This roughened surface is very distinct in the cast of a large specimen (R 3969) from Malta. The proximal radial articulating surface is about 21 mm. wide and that of the humeral articulation 23 mm.; there is a pit, probably for the attachment of a ligament, at the middle of the shaft on its pre-axial edge. The bone is considerably twisted and the pre-axial border much curved. Though smaller the Menorcan ulna resembles that of *T. grandidieri* in general conformation, except that its distal extremity is squarer in outline and the lower half of the post-axial border more prominent.

Pelvic Arch.—This is represented by an imperfect right innominate bone and two ilia, all of considerable size, though far from equalling the proportions of some of the other bones from Menorca. The Spratt collection from Malta only includes three fragments of this bone referred to *T. robusta*, none of which are sufficiently preserved to be of assistance for comparison. Besides this there is in the national collection a cast (R 3972) of the acetabular region of a very large individual also from Malta. The greatest diameter of the acetabulum is 9·3 cm.

Neither of the Menorcan ilia is in a good state of preservation: that of the right side is 11·9 cm. in extreme length and has a greatest thickness of 2·6 cm., though both these measurements must have originally been slightly more. In that of the left side the acetabular articulating surface is present and has a width of 3·4 cm. This example is still adhering to the matrix on its ischial border.

The right innominate bone is still partially embedded in the matrix and is considerably damaged, the upper half of the ilium being wanting and the pubis and ischium in a fragmentary condition. The obturator foramen is ovoid in shape and has a greatest diameter of about 3·9 cm. The pelvis differs considerably among the gigantic tortoises; in *T. ponderosa*[1] the lower portions of the pubic bones are much extended, together forming a beak-like process. This character does not obtain in that of *T. elephantopus*,[2] which the Menorcan example seems to closely resemble.

Femur.—The collection includes an imperfect specimen of small size and the proximal ends of three others, none of which approach in size the humeri described above. The small femur is of the right side and has a total length of 11 cm., and the smallest circumference of the shaft is 5·5 cm. Part of the distal extremity is missing and the proximal end is much damaged, but it can be seen that there is no intertrochanteric notch and probably none between

[1] Günther, op. cit., pl. xviii. [2] Ibid., pl. lii.

the greater trochanter and the head. The largest of the three proximal ends (Text-fig. 2) is very fragmentary, but shows that both upper and lower aspects of the shaft were much flattened.

In the second most of the greater trochanter is missing, but there was evidently no intertrochanteric notch, nor any more than the shallowest groove between the head and the greater trochanter.

The specimen shown in Fig. 2 (2, 2*a*) is of the right side and small in size. The shaft is slender, its circumference being only 4·5 cm. a short distance below the head, which has a largest diameter of

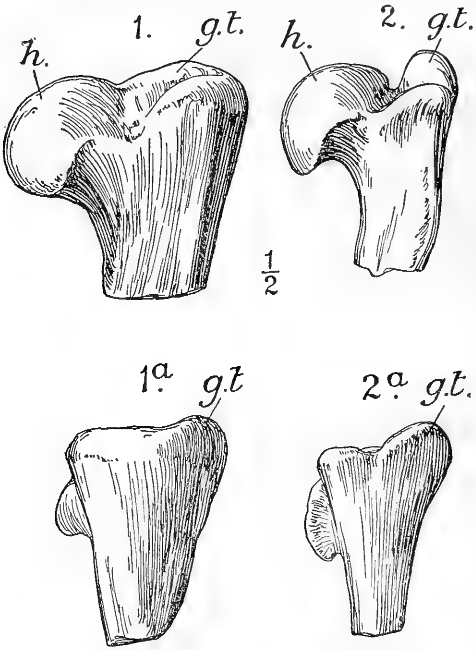
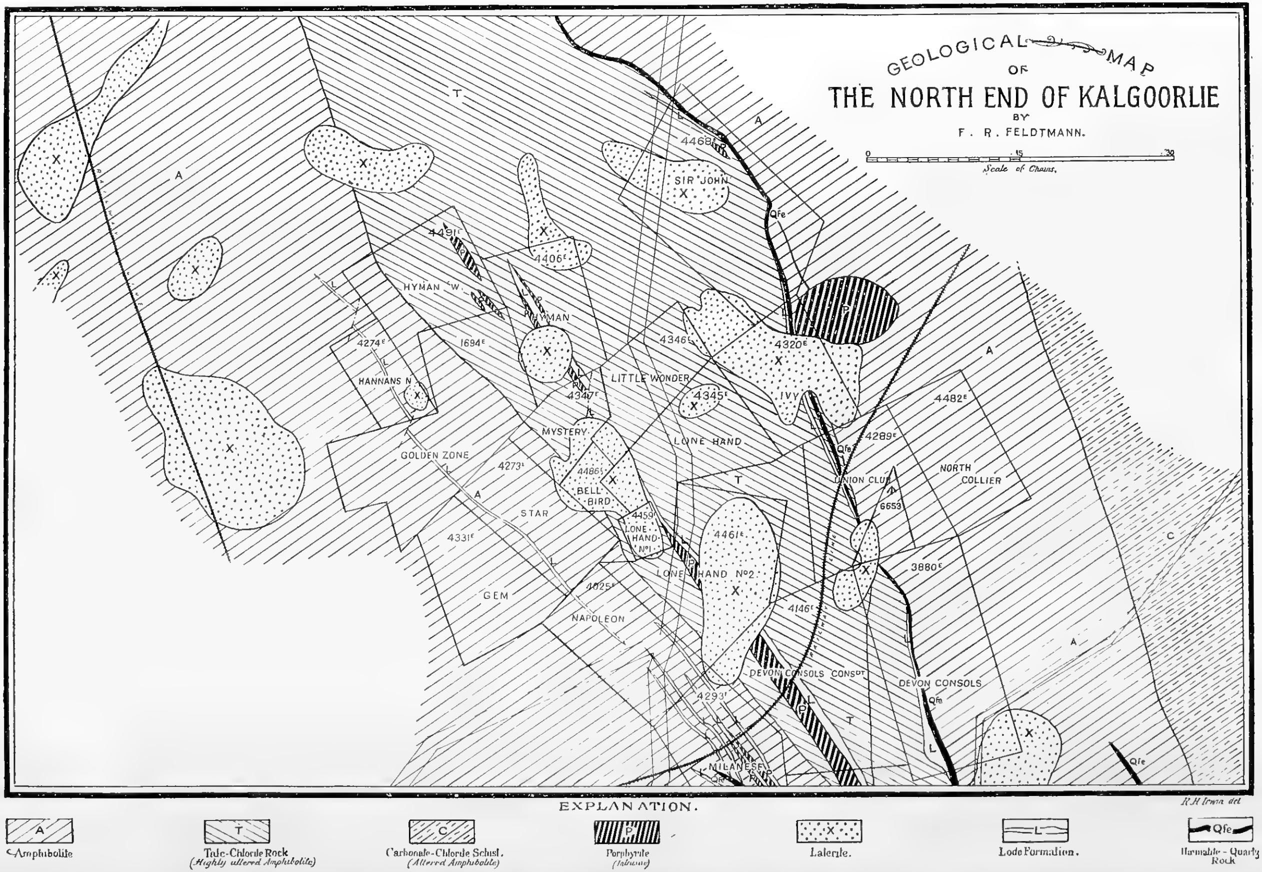


FIG. 2.—Upper ends of two right femora of (?) *Testudo gymnesicus*. 1, 2, anterior face; 1*a*, 2*a*, ventral face. *h*. head of femur; *g.t.* great trochanter. ½ nat. size.

barely 3 cm. It differs from the other examples in the greater trochanter rising considerably above the lesser, in the presence of a shallow groove between the two trochanters, and a deeply excavated one between the greater trochanter and the head. Though very inferior in size, in these other respects it is not unlike the proximal end of a femur of *T. robusta* in the national collection.[1] The difference between the Menorcan specimens is well shown in Text-fig. 2. In all three the pit between the head and the trochanters is of considerable size and depth, though in the second this is only inferred as the hollow is still partially filled with matrix.

[1] Described and figured by Leith Adams, Quart. Journ. Geol. Soc., vol. xxxiii, pl. v, figs. 4, 4*a*, 4*b*, 1877.



To illustrate paper by Mr. R. A. Farquharson on the Petrology of North Kalgoorlie.

Tibia.—Owing to its imperfect state of preservation one specimen obtained presents some difficulty in determination, but it is thought to be the proximal end of a tibia. It belongs to the right side and has both the anterior and posterior tuberosities damaged. It is of considerable size; the shaft is flattened posteriorly, and its circumference at the break is nearly 10 cm. The width of the femoral articular surface is 69 mm. in spite of the edge of the external tuberosity being missing. This measurement is not quite attained by any of the corresponding bones of *T. grandidieri* in the national collection, and greatly exceeds that of the larger specimen in the earlier collection from Malta. Among the casts presented by Mr. Tagliaferro is that of a nearly perfect right tibia of much larger proportions than any of the above.

Phalanges.—The collection includes an almost perfect specimen of a small terminal phalanx; it is comparatively wide for its length, measuring 16 mm. across by 27 in length. The constriction at its articular end is more marked than in the specimens from Malta.

III.—Notes on the Petrology of a portion of the North Kalgoorlie Field.[1]

By R. A. Farquharson, M.A. (Oxon.), M. Sc., F.G.S.,
Petrologist to the Mines Department of Western Australia.

(PLATES V–VII.[2])

Contents.

I. Introduction.

The majority of the numerous papers that have already been published on the petrology of Kalgoorlie have dealt with the subject only in a more or less general way. Few investigators have hitherto devoted their energies to the study of one portion of the field, and even Larcombe, whose main thesis[3] seems to have been the study of the Golden Mile, has chosen an area in which owing to the magnitude and depth of the lode formations, and the consequent chemical and thermodynamic alterations, definite clues as to the original rock types could hardly be expected to remain, since there can be no doubt that in petrology, as in stratigraphy, much light can occasionally be thrown on the most difficult portions of a field by the study of the outlying portion. It has therefore been with considerable interest that the investigation of the North End has been begun.

[1] By permission of the Director of the Western Australia Geological Survey.
[2] [Plates VI and VII will appear in the concluding part of this paper.—Ed.]
[3] *Geology of Kalgoorlie.*

It is held from facts that can be established in this and adjoining areas, with regard both to the lodes and the country rocks, that the changes taking place progressively towards the most complex portions of the field can be gradually traced, and identification made on reliable evidence that may not be forthcoming in the latter. It may, of course, happen that there are several points even at the beginning that have to be left undecided, and we shall see that this is certainly the case in the North End, but it is hoped that the investigation of the succeeding portion of the field will clear up the difficulties and obscurities surrounding these.

Though the writer was enabled to spend a few days going over the ground, the field work has been entirely done by Mr. Feldtmann, and the specimens representative of the area were largely collected by the same officer, but the collection has been supplemented by the specimens already in the Survey Museum which have been taken from time to time by other officers of the department past and present, viz. Messrs. Beecher, Campbell, Gibson, and the Government Geologist Mr. A. Gibb Maitland.

2. Previous Literature.

Practically nothing has been written so far on the North End. Gibson[1] makes mention of it in places, but only in the most general way. Larcombe[2] dismisses it with a reference to a plan and section.[3] He does not mention the appearance of any porphyrite (keratophyre), though he notes that amphibolites occur at the North End.

3. Classification of the Rocks.

Altogether about sixty specimens have been sliced and examined.[4] In the main, as regards colour, the rocks fall into two broad groups: (*a*) those of a yellowish or brownish tint, and (*b*) those of a greenish tint, which varies from greyish to deep green. The former are, as a rule, hard, but the latter[5] are all in the soft, somewhat clayey rocks with a more or less pronounced soapy feel. Much difficulty has been encountered in the study of the specimens. With very few exceptions—some of the porphyrites and a few doleritic or gabbroid rocks—the whole collection consists of specimens that have been intensely altered, in some cases so altered that no trace whatever of original structures now remain. In most cases only diligent search, with high-power lenses, has enabled such clues as remains of felspars and pseudomorphs and felspars and ferro-magnesians to be detected,

[1] Geol. Soc. W. Australia, Bulletin 42.

[2] Loc. cit.

[3] Plate v, Geological plan and section of the Tea Gardens.

[4] Of those of this number that were obtained by previous collectors, two, viz. Nos. 2918 and 11096, find no counterparts among Mr. Feldtmann's collection. No. 2198 was obtained from the extreme north-west of the area under consideration, and from a dump so weathered as to yield no specimens of any service. The locality from which 11096 was brought has been noted in such vague terms as to render it impossible now to trace the specimen in the field.

[5] With the exception of Nos. 12322 and 12324.

and frequently, even when they have been discovered, there is no residue of the original rock structure. However, since very similar chloritic planes may result both from an acid rock with ferro-magnesians and from a basic one, if neither the character of the felspar can be determined, nor any original structure be discovered, discrimination between the two chlorite phases becomes almost, if not quite, impossible, even with recourse to chemical analysis. By careful study and correlation, however, the following classification has been drawn up:—

A. The quartz-keratophyres, with or without phenocrysts of hornblende, and with or without tourmaline.
B. Those rocks most probably derived from gabbros or dolerites.
  1. Epidiorite group.
C. The talc-chlorite rocks, derived from amphibolitic or other basic rocks, but with indistinct, if any, remains of structure.
D. Rocks of doubtful origin.
  1. The 'fuchsite' rocks with or without tourmaline.
  2. Rocks of possible plutonic origin.

As a rule the identification of rocks belonging to group A has presented no great difficulty, but there are cases in which a determination cannot be made with certainty. Such a case is presented by 12372A. This specimen is a greyish-green rock that is characterized by a considerable amount of scaly chlorite, granular and idiomorphic carbonate, and remains of felspars, which raises doubts as to whether it should be classed as a highly chloritic phase of the porphyrite or as a phase of the dolerite or gabbro. It has been shown recently by Kirk[1] how in the neighbourhood of veins—in the particular case copper veins—a rock as acid as a hornblende granite has developed both a chloritic and a sericitic phase. Describing the latter, Kirk remarks: "Grading laterally from the fresh granite is a chloritised facies having many characteristics analogous to those of propylitised rocks. . . ."

In 12372A, moreover, in the case in which twinned felspar remains admit of measurements of the extinction angles, the species appears to be either albite or albite-oligoclase. The crystals, too, do occur in forms strongly suggestive of their being phenocrysts. The comparatively large amount of chlorite, however, and the large amount of idiomorphic carbonate, with patches of rutile, suggest a relationship with the more basic dolerites.

Again, in the area under review, there are several specimens[2] which consist now of a fine granular mixture of quartz, sericite, calcite, sometimes fine scaly chlorite, and some doubtful particles of leucoxene. These rocks, since no trace of original structure is discernible, have been classed amongst those of doubtful origin (see later on). Now, Kirk, in the paper already referred to, treating of the origin and significance of sericite states[3]: "All the above references indicate that where sericite can be certainly identified,

[1] *Economic Geology: Mineralization in Copper Veins at Butte, Montana*, vol. vii, No. 1.
[2] i.e. 12381, S. 610, S. 188.
[3] Op. cit., vol. vii, No. 1, p. 57.

it becomes a useful corroborative criterion in the interpretation of previous hydro-thermal high pressure conditions. It has been observed to be always a secondary mineral not adjusted to the belt of weathering. The mineral develops typically by hot spring action. . . ."

Further, in his description of the rocks of Cape Colville Peninsula, New Zealand,[1] Professor Sollas describes specimens that were sent to him from localities very rich in rocks of andesite and porphyrite character as quartz-sericite rocks of indeterminable origin. If it is borne in mind that tourmaline is quite prevalent in the North End, except in the lodes, and that its formation is generally held to be due to solfataric or pneumatolytic action, there appears at least a possibility that the specimens are the altered product of the quartz-keratophyre rock.

Again, in some instances, no clear line of demarcation can be drawn between groups B and C. By alteration and subsequent elimination of the felspar, and conversion of the augite to hornblende and chlorite, gabbros and dolerites may pass easily into rocks indistinguishable from some of those of C. Since the change from augite to hornblende by the action of dynamic agencies is now recognized to be a common one, the intermediate stage of diorite and amphibolite may also have occurred, so that some of the altered rocks may show resemblances more to the amphibolites than to the original gabbros or dolerites. The bases of distinction that have been adopted between the two groups are more or less arbitrary, viz., the presence or absence of the remains of felspars, and a recognizable structure.

4. Description of the Rocks.

A. The Quartz-Keratophyre.

1. *General.*

Of the field relations of this rock little can be said with certainty. Nowhere does it outcrop at the surface. Though specimens have been collected from various dumps, in most cases the shafts associated with these dumps are now inaccessible. In the few instances in which the rock is found in the mines, it occurs in association with talc-chlorite rocks, but owing to the great amount of alteration of various sorts its relations cannot be made out with any degree of clearness. According to Mr. Feldtmann, however, there are a few instances in which it does occur in tongue-shaped and dyke-like masses, as at the 120 ft. level, south shaft of G.M.L., 4406 E., Hyman, and consequently is to be regarded on field occurrence more as an intrusive porphyrite than as an andesite.

Characteristic of the rock-mass is its peculiar blotchy or jointed structure. In hand - specimens from yellowish - brown to dark brownish-grey the specimens are, for the most part, comparatively fresh, of medium grain, and with occasional small phenocrysts of felspar. In the darker varieties small green spots are frequently observable, while in all varieties are minute brownish-red patches,

[1] *Rocks of Cape Colville Peninsula,* vol. i, pp. 135–7.

which prove, on examination, to be decomposed pyrites or ferromagnesian crystals. Especially noticeable in a few samples, e.g. 12331A, are rather lenticular patches, sometimes $1\frac{1}{2}$ inches in length and $\frac{1}{2}$ in. in width, composed of a pale-green chlorite, some limonitic iron-ore, and strings of very fresh needles of dark-green tourmaline. In such an advanced stage of alteration are these patches that it is impossible to say definitely from the evidence available whether they are original or represent xenoliths that have been altered partly by ordinary chemical agencies and partly by a kind of pneumatolytic action. It certainly would appear that the keratophyre when near the temperature of consolidation, but still more or less viscous, had enclosed within its mass fragments of greenstone, and that the tourmaline had been produced as a contact-metamorphic product by vapours containing boron associated with the intrusive. On the other hand, not only does tourmaline occur in some of the slides fresh and with no connexion with chlorite, but the felspars and the rock itself in these cases are quite fresh. Unless, therefore, the specimens have been collected from the margins of the keratophyre, and the tourmaline is, in consequence, due to a partial impregnation of the rock by boric vapours, it is difficult to see how in the latter case the mineral can be regarded as other than original.

Regarding the occurrence of tourmaline, Clarke[1] states: "In igneous rocks it seems to have been produced by fumarole action, and not as a direct separation from the magma."

Van Hise writes[2]: "Tourmaline rather frequently occurs in the marbles and in the calcareous schists; it also has a rather widespread occurrence in granites, gneisses, etc. In these rocks it frequently occurs in such relation to dykes of igneous rocks, especially of pegmatites, as to suggest that its development is promoted by contact action. Because of the boron, tourmaline has generally been regarded as evidence of fumarole action. Certain it is that boron is not usually a constituent of the ordinary sediments, and to account for this element would seem to require its introduction from an outside source, either by gaseous or by aqueous solutions."

The occurrence of the mineral in the North End is not restricted to the keratophyre. Indeed, according to the field evidence the mineral is especially common in the lode formation, which consists of kaolin and sericitic material seamed with quartz and quartz-tourmaline leaders. Moreover, in the Mystery Lode in the altered keratophyre contiguous to the lode material, small nests of the mineral have been found which appear to be partially moulded by gold. From this it is probable that the gold is not contemporaneous with the tourmaline, but has been formed at a later date by percolating solutions. Further, as will be seen later on, there are specimens of the quartz-carbonate-fuchsite rock, apparently on the margin of which occur strings of tourmaline.

Most noteworthy of all are specimens 12331B and 12237. These are both from the same locality, viz. G.M.L., 4458 E. They are both light-coloured rocks with a faint reddish tinge, and both show distinct

[1] Clarke, *Data of Geo-chemistry*, p. 347.
[2] Van Hise, *Treatise on Metamorphism*, p. 326.

evidences of shearing. Along the shear planes there has been sometimes a deposition of dendritic manganese oxide. The most important feature about them, however, is the presence, particularly in 12331B, of numerous irregular greenish patches, apparently embedded in a keratophyre mass. These patches, which are soft, very minutely scaly, and with a faint lustre, vary in size from ¼ up to 1 inch in length and breadth, and are generally, though not always, flattened parallel to the line of shearing. They are much weathered, and apparently consist wholly of minute scales of chlorite. Owing to their presence, the rock has at first sight the appearance of a breccia, but a careful examination of the material shows it to be without doubt the keratophyre.

The question arises as to what is the origin of the green fragmentary forms. Both rock specimens were obtained from the same dump, but access to the shaft associated with it was impossible. An examination of the dump, however, shows that from the one shaft there have been thrown out both the porphyritic rock with the green forms and a very much weathered soft-green schist. It proved impossible to obtain anything like a fresh specimen of the latter, but from an examination of a slice of the most suitable material obtainable it was identifiable as a fine-grained chlorite schist. Moreover, though all the rocks are extremely weathered, there seems little doubt that the green fragments and the chloritic schist are identical. Further, the green forms are all essentially of an angular nature; they show no trace of crystal outline, they are themselves schistose.

Taking these facts in conjunction with the sheared nature of the keratophyre 'matrix', the most feasible interpretation of the occurrence is undoubtedly that the green fragments are true xenoliths. Owing to the decomposed nature of the rock, however, the question is a doubtful one. There is, of course, another interpretation, namely, that the enclosures owe the circumstances of their occurrence to the shearing of the keratophyre—that they have, in fact, been sheared into it. It must be admitted that in no case does any assimilation of the chloritic schist and the 'matrix' seem to have taken place; also the majority of the enclosures appear flattened parallel to the plane of shearing. On the other hand, in specimen 12237, in which the shearing effect is not so pronounced as in 12331B, the enclosures are sometimes only partially flattened, and in places appear to be nearly normal to the shear plane. In addition, though there are numerous green particles scattered through the rock, no granulation of the larger xenoliths can be observed, and there is little drawing out of the latter into lenticular forms.

2. *In Detail.*

The external characteristics have already been given. In some of the freshest specimens green spots are visible which are not referable to tourmaline, but which in section prove indisputably to be chloritized phenocrysts of hornblende.

Numerous determinations have previously been made of rocks more or less identical with these, and such names as felspar-porphyry, porphyrite, felspar-porphyrite, etc., have been given to them.

Several facts, however, have hitherto completely escaped notice. In the first place, while the rocks in general are undoubtedly composed almost entirely of felspar, and the mineral occurs frequently as phenocrysts, there are quite a number of instances in which no phenocrysts are present, and the rock is apparently wholly made up of small rectangular and columnar laths of the mineral, without, however, any 'flow' or 'trachytic' structure. Moreover, the character of the felspar is peculiar. Both measurements of the extinction angles on albite lamellæ and chemical analysis show that the mineral is particularly rich in soda; indeed, the percentage of lime in the analysis is so small that it can no doubt be all accounted for by the presence of (decomposed) ferro-magnesians. No potash whatever appears in the analysis.

Further, there are indisputable evidences of the former presence of phenocrysts of hornblende: six-sided crystal forms showing prismatic angles which measured 125° and 55° have been observed in several instances, and though, owing to chloritization of the mineral, the usual prismatic cleavages are not observable in cross-sections, the six-sided form, so common in cross-sections of hornblende, and to a less extent the occurrence of rectangular and rhombic longitudinal sections, leave no doubt as to the identity of the mineral.

As will shortly be shown, a comparison of the composition, characters, and structure of the rocks establishes their identity with that group which Rosenbusch calls quartz-keratophyres, but which also appears elsewhere as albite-porphyrites. In many ways they agree also with varieties of quartz-andesite, but, though it was impossible to prove the presence of fluid cavities in the quartz, there is no indication of any glassy base; the felspar is evidently albite, and, according to the field evidence, as has been stated, the rocks are at times distinctly intrusive as tongues and narrow dykes.

(*a*) *The Porphyritic Type.*—12331A, 12331C. G.M.L., 4406 E., Hyman.

M.C.[1] A grey rock with faint reddish tinge, and with one enclosure of large size and several of small size, all containing strings or small nests of tourmaline needles.

S.[1] Minerals observed: felspar, quartz, chloritized hornblende, muscovite, brown and black iron-ore in crystals and grains, chlorite.

In ordinary light the section shows scales and flakes of green pleochroic chlorite, brown and black grains of iron-ore, and various sections of chloritized phenocrysts in a clear or slightly brown-stained ground (Pl. VI, Fig. 1). The chloritic sections occur in rhombic, rectangular, and clearly six-sided shapes, and without any doubt represent original hornblende. No tourmaline was seen in the particular section examined, though its presence was visible to the eye in isolated spots in the rock.

Under crossed nicols, besides the chloritized phenocrysts, appear large idiomorphs of fresh, often minutely twinned felspar in a ground-mass of minute laths of the same mineral, and small plates and platy aggregates of quartz (Pl. VI, Fig. 2). Measurements show

[1] M.C. = macroscopic characters; S. = section.

that the felspar is albite or albite-oligoclase. The ground-mass consists of innumerable fine laths of twinned felspar with, in places, an approach to felted structure, a fact which tends to show that the rock consolidated sensibly under atmospheric pressure conditions. Quartz occurs not only in minute plates, but also in mosaic aggregates and in one or two rather large forms, which are, however, quite without definite outline. In some places the felspar phenocrysts present corroded margins as if the ground-mass had reacted on the phenocrysts. In other cases they appear to be partially replaced by clear quartz and muscovite.

To settle all doubt as to the nature of the predominant mineral a chemical analysis of the rock was made in the Survey laboratory, with this result—

	Per cent.		Per cent.
SiO_2	69·02	*Brought forward*	78·80
TiO_2	·57	MgO	2·63
CO_2	·14	MnO	·09
P_2O_5	·28	FeO	1·90
$H_2O + X$	1·02	Fe_2O_3	·58
K_2O	*nil*	Al_2O_3	15·92
Na_2O	7·48	FeS_2	·11
CaO	·29	H_2O	·28
	78·80	Total	100·31

The absence of K_2O and the high percentage of Na_2O with the low percentage of CaO show conclusively that the species is highly sodic, and mostly, if not wholly, albite. Moreover, the high silica percentage bears out the identification of quartz in the ground-mass.

This analysis was compared with those of some rocks of other localities:—

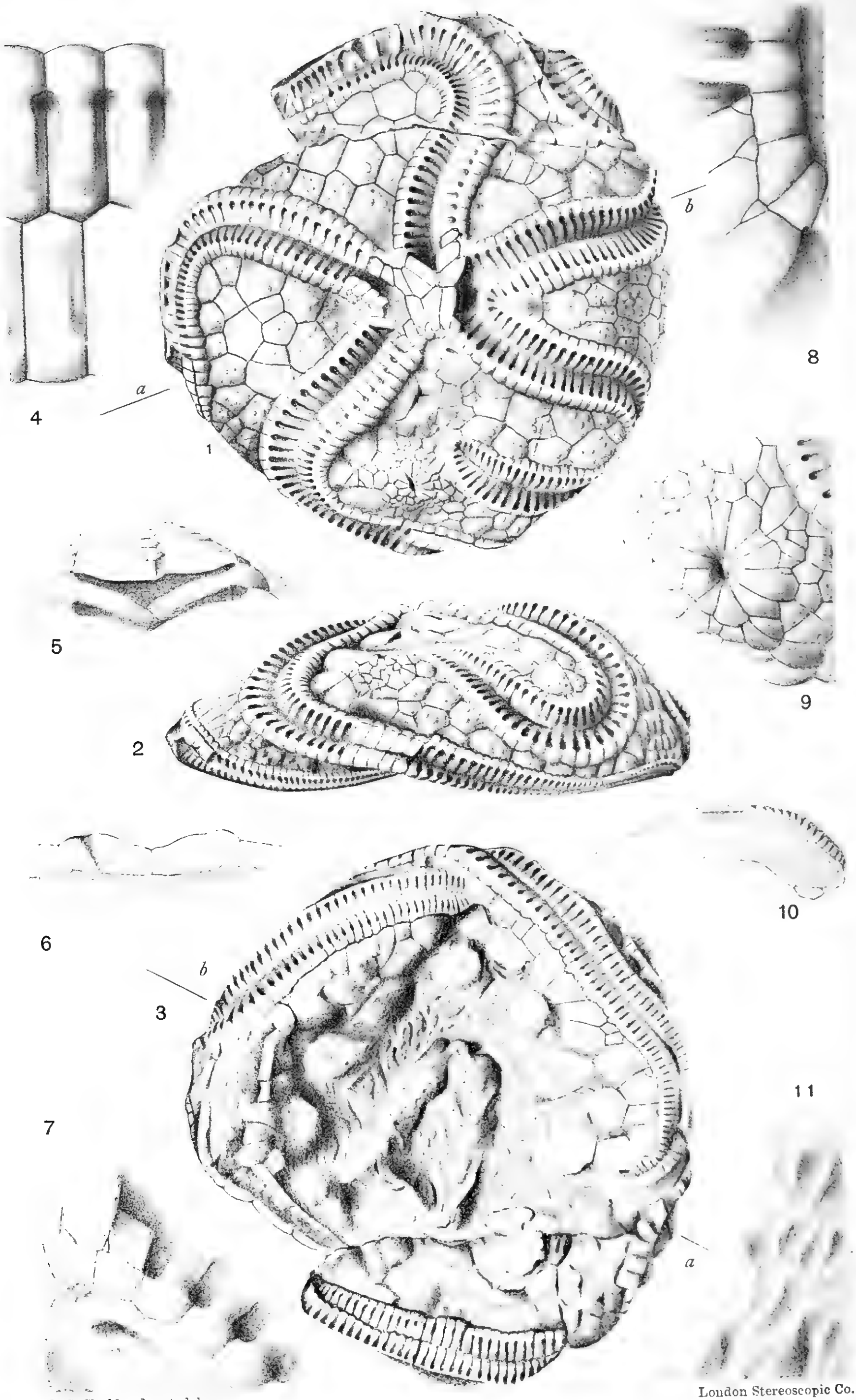
	1	2	3	4	5
SiO_2	68·04	67·90	72·24	72·34	69·02
TiO_2	—	·24	·41	—	·57
Al_2O_3	16·14	14·36	13·85	14·07	15·92
Fe_2O_3	4·32	4·36	1·45	2·92	·58
FeO	·97	1·44	1·86	—	1·90
MnO	—	·32	·12	—	·09
MgO	1·02	·22	1·10	1·27	2·63
CaO	·32	1·34	3·40	·41	·29
Na_2O	7·62	6·89	4·43	6·28	7·48
K_2O	·58	1·85	·39	1·13	*nil*
H_2O	1·27 [1]	1·52	·86	1·41	1·02
P_2O_5	—	—	·10	—	·28
Total	100·28	100·44	100·21	99·83	100·31 [2]

1 Quartz-keratophyre (Rosenbusch, *Gesteinslehre*, 1910, p. 329).
2. ,, ,, ,, ,,
3. Quartz-diorite-porphyrite (Osann, *Beiträge zur chemischen Petrographie*, p. 87).
4. Keratophyre (brown), Osann, p. 120.
5. Analysis of 12331A re-quoted for comparison.

(*To be continued.*)

[1] Glühverlust.

[2] Includes CO_2, FeS_2, and H_2O.



G. C. Chubb ad. nat. del.

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Edrioaster bigsbyi

IV.—Studies in Edrioasteroidea.[1] IV. The Edrioasters of the Trenton Limestone.

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

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(PLATES X–XIV.)[2]

Previous History.

EDRIOASTER bigsbyi was first made known by E. Billings in June, 1854,[3] and was referred by him, though with some doubt, to *Agelacrinites.* He gave no specific name, but regarded his fossils as identical with the specimen found by Bigsby at the Chaudière Falls and described by G. B. Sowerby in 1825 (see Study III), and as "almost identical with *A. Buchianus*" of Forbes, 1848 (see Study II). This series of papers by Billings contains several important observations and reasonings not reproduced in those later more official publications of his to which alone subsequent writers seem to have gone for information. From the original account it is clear that the specimens there called *Agelacrinites* were the same as those which Billings described in 1857, under the name *Cyclaster bigsbyi.*[4] The misapprehension that caused Billings to apply to his new species the trivial name *bigsbyi* has already been dealt with in Study III; the species has nothing to do with the specimen found by Bigsby. In 1858 Billings discovered and pointed out his error, and, realizing further that the generic name *Cyclaster* had been taken by G. Cotteau for a sea-urchin a few months before his own use of it, he redescribed the species under the name *Edrioaster bigsbyi.*[5] The independence of the genus itself was denied in 1860 by E. J. Chapman, who referred the species back to *Agelacrinites.*[6] The textbook writers, however, generally accepted *Edrioaster*, and no change was made in either name or description until Professor Haeckel in 1896 thought fit to alter the name to *Edriocystis.*[7] Neither the nomenclatoral nor the taxonomic vagaries of Professor Haeckel won any favour, and it is needless to allude further to him or to other writers who shared his ignorance of the facts but not his imagination. In that category I do not include Professor O. Jaekel, but even he, in his *Stammesgeschichte der Pelmatozoen* (1899, p. 46), contented himself with the information and figures published by Billings in 1858, apart from such hints as he could glean from the manuscript of my then forthcoming Study II.

[1] Studies I, II, and III were published in the Geological Magazine for December, 1898, May, 1900, and December, 1908. Plates X and XI of the present Study were drawn in 1900, and diagrams made from the specimen represented in Plate X have been published by me in 1900, 1901, 1902, and 1911. The completion of the present paper has unfortunately been delayed by the pressure of official duties and other scientific work.

[2] [Plates XIII and XIV will appear with the continuation of this paper in the April Number.—Ed. Geol. Mag.]

[3] Canad. Journ., vol. ii, pp. 271–4, figs. 10–12.

[4] Rep. Progress Geol. Surv. Canada, 1853–6, p. 293, Toronto, autumn of 1857.

[5] Canad. Org. Rem., dec. III, p. 82, pl. viii, figs. 1, 1*a*, 2, 2*a*, June, 1858.

[6] Canad. Journ., N.S., vol. v, p. 364.

[7] "Amphorideen und Cystideen," pp. 117–8, Festschr. f. Gegenbaur, 1896.

In brief, then, from the time of Billings down to the end of last century, the genus *Edrioaster* remained most imperfectly, not to say incorrectly, apprehended. Its importance was obvious, but I did not dare to introduce it into any system of classification or any theoretical discussion without having first-hand knowledge. The opportunity for obtaining this was afforded by my friends Mr. Walter R. Billings, of Ottawa, and the late J. F. Whiteaves, of the Canadian Geological Survey, who lent me excellent material, which I was fortunately allowed to retain for several years. The need of time as well as of material has never been more obvious. Before any precise account could be written or any adequate figure drawn, it was necessary to clean and develop the specimens with the utmost patience. And here I have to acknowledge the great help rendered by my wife, who devoted months of labour to a single specimen, thus enabling Mr. G. C. Chubb to make the admirable drawings on Plate X. The information thus obtained was utilized in the diagrams and brief account of *Edrioaster bigsbyi* published in *A Treatise on Zoology*, vol. iii, Echinoderma, p. 209 (London, 1900), in the abstract of a lecture "What is an Echinoderm?" [1] and in the *Encyclopædia Britannica* articles on "Echinodermata" (1902) and "Echinoderma" (February, 1911). That specimen has been still further cleaned, several other specimens have been prepared and studied, and the results are given in the present paper.

Since 1900 the only author to pay any particular attention to my publications on Edrioasteroidea has been Mr. W. K. Spencer, who criticized some of my conclusions in his interesting paper "On the Structure and Affinities of *Palæodiscus* and *Agelacrinus*" (Proc. Roy. Soc., vol. lxxiv, pp. 31–46, pl. i, 1904), but who has since modified his objections ("Brit. Palæoz. Asterozoa": Palæont. Soc. vol. for 1913).

Material.

The holotype of *Edrioaster bigsbyi* has never yet been fixed, and should be chosen from among the original specimens described and named by E. Billings (1857). On the generally admitted assumption that these comprised the original of Billings' pl. viii, fig. 1 (1858), I hereby select that specimen as holotype. This and the other specimens described and figured by Billings in 1857 and 1858 are kept in the Victoria Memorial Museum at Ottawa. These specimens are so imperfectly preserved that Mr. Whiteaves did not consider it worth while to send them to me. He sent, however, the following three specimens, the property of the same museum, and belonging without any doubt to the same species. For convenience of reference I have lettered them A–C.

A. The original of Plate X. A theca in calcite in a matrix of very hard, grey, shaly limestone, which, when the specimen was sent me, covered the whole of its under face, but is now cleaned away. The specimen is broken into three parts by a crack across the anterior ray and another across the distal end of the right anterior ray. Part of the theca comprising the distal end of the anterior ray is missing.

[1] Journ. London Coll. Sci. Soc., vol. viii, pp. 21–33, May, 1901. Also *Che cosa è un Echinoderma?* Torino, October, 1901.

B. The original of Plate XI. A theca lying on a small block of hard, black, shaly limestone, so that only the upper face is exposed. This retains the cover-plates, which, however, are crushed in.

C. The original of Plate XIII. A theca of which the upper or oral face is covered with yellowish matrix, but of which the under or adapical face has been well exposed.

In the absence of detailed information, it is assumed that these specimens came from the neighbourhood of Ottawa, as did all those mentioned by E. Billings.

Mr. Walter R. Billings lent me the following specimens of the genus, and ultimately with singular generosity presented them to the British Museum, under whose register numbers they are here quoted.

E 16173, a medium-sized specimen, with radius *ca.* 18·5 mm. Adoral face disturbed and weathered, with hard black shale in the hollows. Adapical face worn, and obscured in centre by hard limestone matrix. Collected by W. R. Billings at Belleville, Ont., on right bank of the Moira, a quarter of a mile above the railway bridge (*E. levis*).

E 16172, a smaller specimen, with radius *ca.* 16 mm. Most of the right side is missing; rest of adoral face fairly preserved. Adapical face partly obscured by limestone and grey shale, since removed. Collected by W. R. Billings at Peterborough, Ont. (Pl. XIV, Figs. 2, 3.)

The British Museum has still more recently acquired—

E 15930, a rather large individual, radius *ca.* 25 mm., poorly preserved. Adoral face much rubbed. Adapical face coated with hard black shale, now removed. From Mount Sherwood, a suburb of Ottawa. W. R. Smith Collection, 1909. (Pl. XIV, Fig. 1.)

E 16054, a smaller individual, radius *ca.* 11 mm., preserved obliquely and therefore less flattened, in a brown, sandy, calcareous shale. From Belleville, Ont. W. R. Smith Collection, 1909.

E 15900, a rather large individual, radius *ca.* 23 mm. Adoral face fairly well preserved. Part of the adapical face exposed. Matrix a dark-grey shale. From Kirkfield, Ont. Presented by Professor W. A. Parks, 1909. (*E. levis*, Plate XII.)

Horizon.

All the known specimens are from the Trenton Limestone.

In the absence of more precise information, I take the horizon at Ottawa to be probably the limestone with shale partings which Dr. P. E. Raymond (1912[1]) assigns to his Horizon 5; but it is also possible that some specimens are from his lower Horizon 2, which is exposed in the Hull quarries. E. Billings (1854, p. 272) found "seven specimens . . . within a space of four square yards in extent, and partially embedded in the surface of a stratum of limestone. Along with them were" trilobites, crinoids, *Amygdalocystis tenuistriatus*, and a quantity of *Chætetes lycoperdon*. These, with others, were all "in the upper one hundred feet of the Trenton limestone" (p. 273).

[1] 1912, Summary Rep. Geol. Surv. Canada, 1911, p. 354.

Specimen E 15900 from Kirkfield is probably from Horizon 2, which is well developed at that place.

I have no external evidence as to the horizon of the specimens from near Belleville, or of that from Peterborough.

E. bigsbyi has also been recorded from the *Fusispira* and *Nematopora* beds, in the middle of the Trenton group, in Minnesota (N. H. Winchell & E. O. Ulrich, Final Rep. Geol. Surv. Minnesota, vol. iii, pt. ii, p. cxxiii, 1897).

General Description.

The theca has an approximately circular periphery, and a diameter varying between 20 and 50 mm. As in *Dinocystis barroisi* (Study I) and *Edrioaster buchianus* (Study II), the general shape is that of a Tam-o'-Shanter cap or a Breton béret (Text-fig. 1).

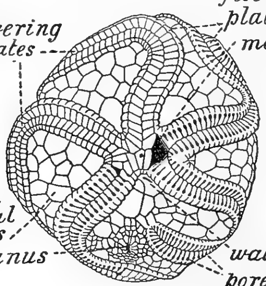


Fig. 1. *Edrioaster bigsbyi.* The adoral face, slightly restored from specimen A. The cover-plates are removed from rays I, IV, and V, but remain on rays II and III. Natural size.

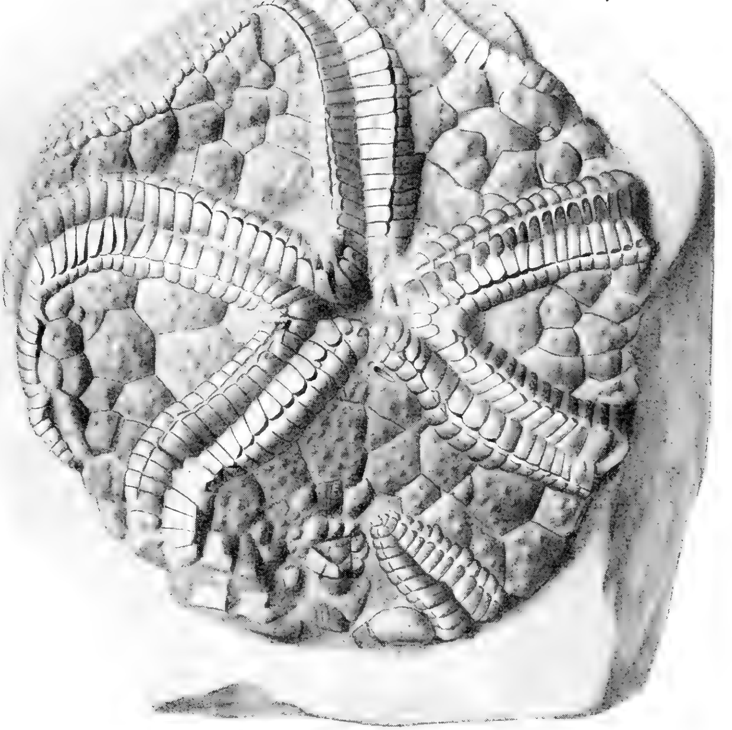
The mouth is at or near the centre of the convex face, and from it five subvective grooves pass over the theca on to the concave face. Each groove is sharply curved as it approaches the periphery; the curve of the right posterior is probably always solar (= dextral), that of the others is contrasolar in the type-species. Each groove is floored by an alternating series of plates (floor-plates), and roofed by alternating movable cover-plates, one to each floor-plate. The median line of each groove is depressed to form a channel, from which branches are given off to right and left between the floor-plates. Each branch ends at a pore, which passes down the suture between the adjacent floor-plates into the thecal cavity. These pores are close to the margins of the groove, but beneath the cover-plates.

The mouth opening (peristome) is surrounded by skeletal elements continuous with the floor-plates, and is roofed by plates continuous with the cover-plates.

The thecal plates of the convex face between the rays (interradials or interambulacrals) are relatively large, irregular in shape and size, and do not imbricate.

In the posterior interradius, two large interradials, adjoining the peristome, are traversed by an elongate hydropore.

1



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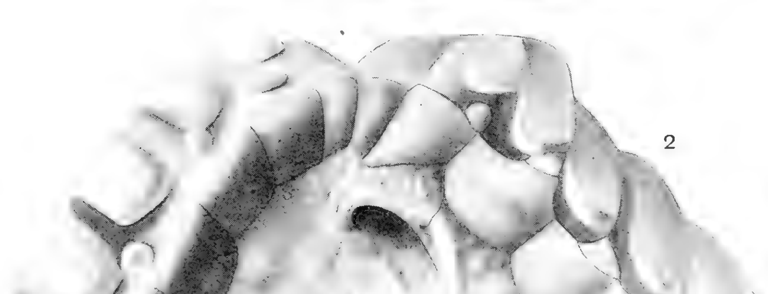

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EDRIOASTER BIGSBYI.

In the same interradius lies the anal opening (periproct), surrounded by smaller interradials.

On the concave face are seen the ends of the rays, stiffening the periphery. Within them are some irregular plates continuous with the interradials; and then a circular frame of rather larger and stouter plates. Loosely stretched across the space within this frame was a flexible integument, filled with minute plates. This integument was generally protruded round the centre in roughly U-shaped lobes, apparently five in all, but often irregular, at least in the fossils.

Detailed Description.

This is based mainly on specimen A, but measurements and occasional details are also given on the evidence of the other specimens. It will soon be manifest that specimens E 16173 and E 15900 represent a species distinct from *E. bigsbyi*, to which all the other specimens appear to belong. For this new species the name *E. levis* is proposed.

The Periphery is roughly circular, with irregular swellings and indentations formed by the rays, and varying in position according to the curvature of the rays. The circular form is sometimes further departed from, in consequence of either natural growth or post-mortem pressure, as appears from the following measurements in millimetres :—

	A	B	C	E 15900	E 16173
Sagittal diameter . .	36·2	43·5	*ca.* 37	*ca.* 40	36
Transverse diameter . .	34·5	46·4	*ca.* 37	*ca.* 40	35·6

From the periphery, the theca rises steeply at first, but soon bends adorally in a low arch; towards the adapical face it bends rapidly downwards and inwards, and turns upwards as soon as the rays are passed. When specimen A is placed on a flat surface, the theca reaches a height of 11·5 mm., exactly one-third of its transverse diameter. The adapical face is excavate to about 6·5 mm., so that the length of the polar axis is about 5 mm. The specimen does not appear to have undergone more compression along this axis than it may have been capable of effecting spontaneously during life. It is, however, probable that in life the adapical integument hung lower than it is found in the fossil, so that the height of the excavation would have been about half the total height of the theca under normal conditions. The other specimens are not so preserved as to lend themselves to exact measurement in these respects; but, broadly speaking, the larger the theca the more relatively flattened does it appear. This may be due to subsequent pressure in the plane of bedding. Contrariwise, E 16054, which exceptionally lay oblique to the bedding plane, has had its relative height exaggerated by compression. E. Billings' pl. viii, fig. 1*a* (1858) shows a section across a partly crushed specimen. If this be restored to its probable original shape, the measurements are approximately: thecal diameter, 59 mm.; thecal height, 22 mm.; height of adapical excavation, 13 mm. This is one-sixth larger than any actual specimen I have seen.

Specimens that have clearly been flattened in one or another plane show some displacement of the thecal plates, and this fact, taken together with the solidity of all thecal elements other than the apical integument, shows that the theca as a whole was not particularly flexible.

On the Adoral or Upper Face are the five Radial Grooves, of which the course may first be traced in specimen A (Pl. X, Fig. 1). All proceed with a very slight curve to a distance of about 15 mm. from the oral pole. The antero-lateral and postero-lateral rays have the concave side of this curve turned towards the postero-lateral interradii; in other words the rays of the right-hand pair and of the left-hand pair respectively bend towards each other. In the anterior ray the concavity faces the right. That is to say, the proximal curve of the left posterior, anterior, and right anterior rays (I, III, IV) is solar or dextral, and that of the left anterior and right posterior rays (II, V) is contrasolar or sinistral. All the rays except the right posterior then suddenly bend in a contrasolar direction, and after bordering the periphery for the space of an interradius, pass on to the under surface of the theca, where they continue in the same direction for the further space of an interradius, ending near the adjacent ray (Pl. X, Fig. 3). The only exception to this regularity of these four rays is that the peripheral tract of the right anterior ray bends upwards for a short distance within the right anterior interradius (Pl. X, Fig. 1). The right posterior ray, however, bends in a solar direction, and returns on the posterior interradius, ending on the oral face at a point a little to the right of the periproct, and about 9·5 mm. from the oral pole (Pl. X, Fig. 1). In consequence of this, the peripheral tract of the left posterior ray passes across both the posterior and the right posterior interradii, and ends against the right anterior groove (Pl. X, Fig. 2).

The varying curves of the rays in this specimen A and their sharp definition give them a peculiar aspect of independent life. The width of a ray in the proximal half of its course is 5·5 mm., or slightly less when close to the peristome; where it bends, the width is 4·5 mm.; on the under side it gradually tapers to 3 mm., after which it is rapidly rounded off.

In specimen B the general shape and disposition of the rays is precisely as in A, except that the anterior ray does not begin with a solar curve, but runs straight to the main contrasolar flexure. The width of a groove in the proximal half is about 6·3 mm., but may be reduced to as little as 5·5 mm. at the bend (Plate XI).

In specimen C the adoral region is covered with matrix, but from the marginal tracts it can be inferred that the general disposition of the rays is as in A and B (Plate XIII).

Specimen E 16172, so far as preserved, indicates a similar arrangement.

In E 15930 the proximal curve of the rays is contrasolar in the left posterior, left anterior, and right posterior (I, II, V), and solar in the other two rays. The distal curve of the left posterior, left anterior, and right anterior rays is visible on the under side of the theca and is contrasolar (Plate XIV). Probably the general arrangement was as in A.

E 16054 is a young individual, as shown not merely by its small size, but by the small extent of the periphery occupied by the distal tracts of the rays, which do not stretch half-way across the interambulacrum. Owing to lateral compression, the curves are not very clearly seen. The proximal curve is solar in the right anterior, contrasolar in the right posterior ray, as in A. The distal bend is clearly contrasolar in the left anterior ray, and appears to have been the same in the others, except in the right posterior, where it is solar but cannot be traced far.

The rays in E 16054 are not only relatively shorter, but taper more rapidly than in older individuals. Thus the left anterior ray is 4·1 mm. wide in the extreme proximal region; 3·1 mm. wide at about half-way to the periphery; 2·4 mm. at the periphery, whence it rather quickly rounds off.

Specimens E 15900 and E 16173 (*E. levis*) differ conspicuously from the others in that the main distal curve is solar in all rays, and that the right posterior ray, instead of being recurved, passes along the periphery of the posterior interradius and bends round like the other rays to end on the adapical face. In E 15900 the proximal curve is solar in all rays except the left anterior (II) ray, where it is contrasolar (Plate XII). In E 16173 the proximal tract is not clearly seen in ray II; in all others the curve is solar.

Summing up the evidence before me as to the distal curvature of the rays, it appears that in all individuals that of the right posterior ray, when known, is solar, that in six individuals (A, B, C, E 15930, E 16054, and E 16172) that of all the other known rays is contrasolar, and that in two individuals (E 15900 and E 16173) it is solar. Billings (1858), pl. viii, fig. 2, also represents two rays with a contrasolar bend. Although Billings (1858, p. 83) says that the rays curve "towards the right in some specimens, and towards the left in others", I know of no evidence for a contrasolar bend of the right posterior ray, and seeing that it is solar in all of our six specimens in which the other rays are contrasolar, it is hardly likely to have been contrasolar in any other case. Neither do I find evidence for any individual ray or rays (the right posterior always excepted) bending in a direction contrary to the majority, as does the right anterior in the holotype of *Agelacrinus hamiltonensis*.

In his original account (1854, p. 272) E. Billings said that he had found seven specimens, and that in one only did "the rays turn to the right [solar] instead of the left [contrasolar]". It is therefore curious that in his "partly restored figure" 10 (p. 271) he should have represented all the rays as equably solar. This must have been a pure mistake, for Mr. Walter Billings, who kindly looked up this point for me in April, 1900, said that all the ten imperfect specimens then in the museum at Ottawa showed a contrasolar flexure. The one exception mentioned by E. Billings, further distinguished as showing the adapical face, could not then be found. Subsequently specimen C, with the adapical face exposed, turned up in that museum and was sent to me. In it the rays, though contrasolar, appear solar because seen only from the under face. This may have been the specimen referred to by E. Billings, in which case none of the Ottawa specimens would have the rays solar.

The only certain exceptions to the normal arrangement are E 15900 and E 16173, which have the rays all solar; but these, on account of yet other features, are to be separated as a distinct species, *Edrioaster levis*.

The conclusion, then, is that in *Edrioaster bigsbyi* the bend of the right posterior ray is solar and recurved on the interambulacrum, that of all the others contrasolar. In *E. levis* the bend of all rays is solar, and none is recurved. In *E. buchianus* the rays of the only known specimen have the same arrangement. The same is apparently the case in *E. saratogensis* Ruedemann, 1912. For although Dr. Ruedemann says that one of the rays (inferentially the left posterior) is contrasolar, this is borne out only by his own restoration of a specimen in which that ray is not preserved (pl. iii, fig. 3). In his fig. 2 the proximal tract of the right anterior ray has a slight contrasolar curve; but all other rays in all figures are solar or straight in that region. In *Dinocystis barroisi* and in the holotype of *Lebetodiscus dicksoni* all rays are contrasolar. The facts are summarized in the annexed table.

	Proximal.					Distal.				
	I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
Edrioaster bigsbyi A.	S	C	S	S	C	C	C	C	C	S
,, ,, B.	S	C	R	S	C	C	C	C	C	S
,, ,, C.	?	?	?	?	?	C	C	C	C	S
E 15930	C	C	S	S	C	C	C	C	C	S
E 16054	?	?	?	S	C	C	C	C	C	S
E 16172						C	C	C	C	S
E. levis—										
E 15900	S	C	S	S	S	S	S	S	S	S
E 16173	S	?	S	S	S	S	S	S	S	S
E. buchianus	R	R	S	S	S	S	S	S	S	S
E. saratogensis	S	S	R,S	S,C	S	S	S	S	S	S
Lebetodiscus dicksoni	C	C	R	C	C	C	C	C	C	C
Dinocystis barroisi	C	C	C	C	C	C	C	C	C	C

S = solar; C = contrasolar; R = straight.

Floor-plates.—The main description applies to *E. bigsbyi*, especially to specimen A; the peculiarities of *E. levis* are noted later.

For the whole of their length the radial grooves are floored by a double series of alternating plates, which meet in a zigzag median suture. These floor-plates are elongate at right angles to the median line of the groove, the width of each plate being less than one-third (*ca.* ·28) of its length. Their outer margins are convexly curved; their abutting margins are straight (Pl. X, Fig. 4). The plates rise sharply up from the interradial areas, they form a rounded margin on each side of the groove, and then dip almost straight down to the median suture, where they meet at an angle of about 130° (Pl. X, Fig. 6). Near the peristome this angle is slightly less, that is to say the depression is more marked; but at the distal ends it becomes wider and almost disappears. Where the grooves bend sharply, the dip of the floor-plates on the inner side of the curve becomes steeper, and the angle therefore less. All these changes can be traced in Pl. X, Figs. 1–3.

The suture between two floor-plates of the same side of the groove is depressed from a point just within the rounded margin right down to the median suture. The depression is deepest at its outer end, where also it is slightly expanded in circular form; but thence it gradually widens towards the median suture. That suture also is depressed, so that there is a sinuous median channel (Pl. X, Figs. 4, 5).

Further details of structure in the floor-plates are to be noted. The rise above the general surface of the interradial area may be strongly marked; in B it amounts to *circa* 1·9 mm., and about half-way up this outer part of the plate is a slight depression, which seems to continue the pustular ornament of the interradials.

In the proximal half of a groove, in A, the length of each floor-plate (at right angles to the radius) is about 2·7 mm., and the width (measured parallel to the radius) ·75 mm. In B the latter measurement is as much as 1·14 mm.; but as the groove narrows distally this also decreases, so that in the distal part of the right posterior ray it is noted as ·66 mm. At the extreme distal end of a ray, as seen in A, the floor-plates diminish considerably in size, but continue to alternate, and are arranged fanwise. There is no distinct terminal (Text-fig. 4). These appearances were not clearly exposed when Plate X was drawn.

The groove along the suture between adjacent floor-plates was not really so simple as it appears in most specimens. In the left anterior ray of E 16172 (Pl. XIV, Fig. 3) are seen two slight ridges starting from near the centre of the circular expansion (pore), and diverging as they pass, one on each side of the suture. On the side of each ridge remote from this suture are about three slight swellings, and the ridge itself may thus be broken up into a row of tubercles. Round the circular expansion is a slightly raised rim. These features, when once appreciated, can also be detected in parts of specimen A.

In specimens that have not been thoroughly cleaned, the outer circular ends of the depressions between the floor-plates are filled with matrix, and this, according to its amount, gives the appearance of a series of pores or of slits. If the matrix be also retained between the divergent ridges just described, it may produce the appearance that in 1858 (pl. viii, fig. 2*a*) misled E. Billings into the supposition that there was a second inner series of pores. Careful removal of the matrix entirely does away with the latter appearance, and reduces the supposed outer series of pores to little more than pin-pricks, each in the centre of the circular expansion (Pl. X, Fig. 4). It has in fact been suggested that further cleaning would do away with the appearances altogether, and that pores do not really exist (e.g. Jaekel, 1899, p. 21). The presence of pores, however, is proved by the more direct evidence of sections fortunately provided by the cracks across specimen A. One of these cracks (Pl. X, Fig. 1) passes right through a supposed pore on the left side of the anterior ray; removing the loose portion and examining the fractured surface, one sees the dark stain of the pore passing right through the test to the dark impure limestone that fills the thecal cavity (Pl. X, Fig. 6). This section also shows the oblique suture between the floor-plate and the adjacent interradial, sloping from the exterior inwards towards the perradius; and the pore-canal is seen to have a similar obliquity. A like appearance is seen at the distal fractured end of the right anterior ray, which underlies the broken end of the anterior ray; also at the crack that traverses the same ray at right angles to the main crack.

These pores differ from the so-called pores of the Cystidea in two respects: they pass into the thecal cavity; they do not pierce the substance of the floor-plates, but lie in the suture between them. Just as the depression of that suture on the floor of the radial groove forms a channel leading to the peripodium or circular rim round the pore, so on the interior of the test the suture between the floor-plates is depressed as it nears the outer margin of the ray, and thus the pore-canal opens into an elongate depression, as well seen in a part of the right anterior ray of specimen E 16172 (Pl. XIV, Fig. 2). These depressions are the more conspicuous because the general inner surface of the floor-plates is flush with the inner surface of the interradials. These interior openings of the pores were noted by E. Billings in 1854 (p. 272).

It is clear that the appearances in the stereom of the floor-plates, as just described, form the precise counterpart of the appearances in the matrix and internal casts of *Edrioaster buchianus* as drawn and interpreted in Study II (Geol. Mag., 1900, p. 196, Text-fig. 3). What all these appearances may mean will be discussed later, but the objective reality of the pores in *Edrioaster* will, I trust, no longer be called in question.

Certain other markings near the outer margin of the radial groove will be described in connexion with the cover-plates, to which we now pass, leaving the circumoral modifications of the floor-plates for future consideration.

EXPLANATION OF PLATES X–XII.

Plate X.

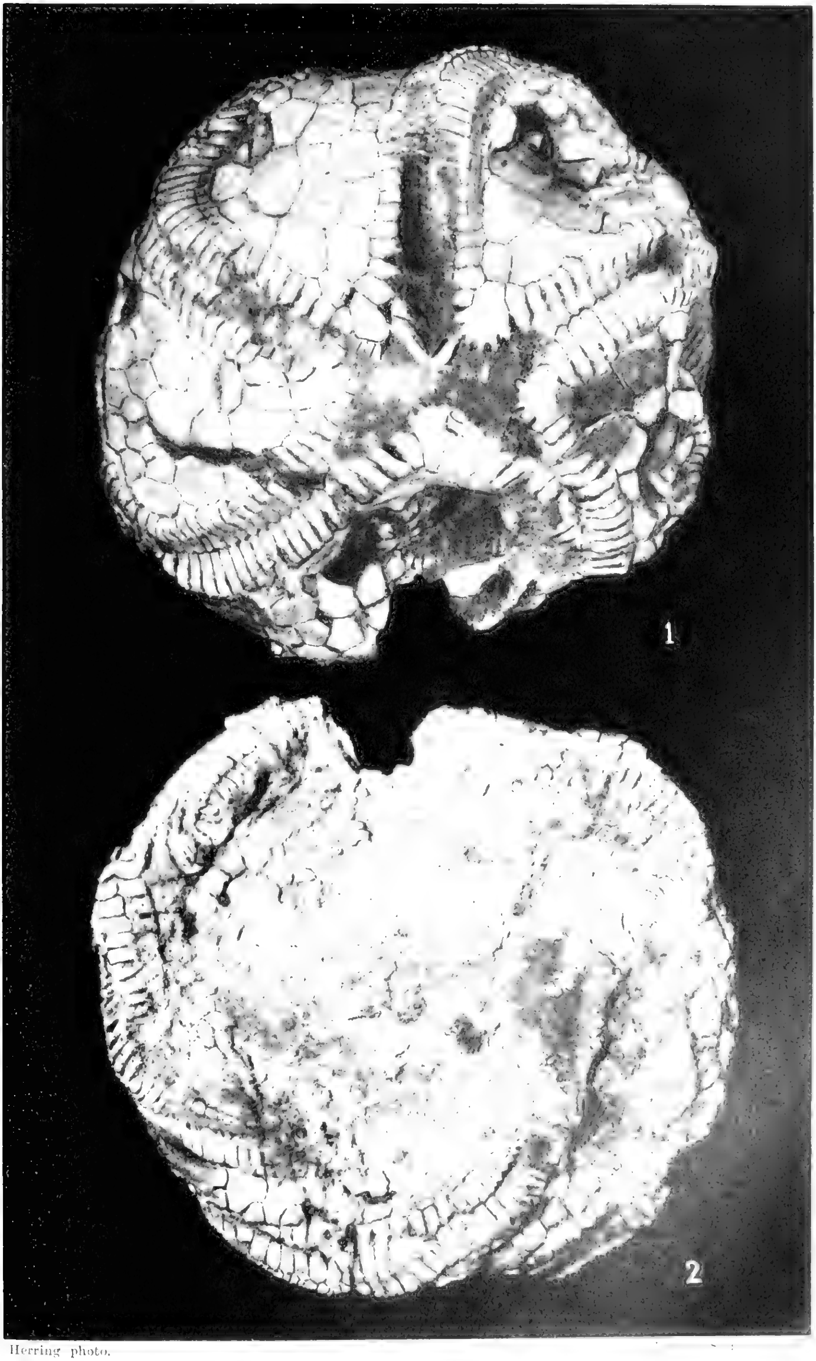
Edrioaster bigsbyi. Specimen A, from drawings made in 1899 by Mr. Gilbert C. Chubb.

Fig. 1. Adoral face. Towards the observer is the posterior interradius, in which are seen the anus and the hydropore. The dark triangular depression between those structures is due to fracture of the plates. × 2 diam.

Fig. 2. Posterior view. × 2 diam.

Fig. 3. Adapical face, the posterior interradius being away from the observer. × 2 diam.

Fig. 4. Some of the floor-plates, showing the groove that leads from the poral depression to the main radial channel. The depression for the cover-plates is not clear in this lighting. × 10 diam.



Herring photo.

LIRIOASTER LEVIS

Fig. 5. A solid section across the food-groove to show the relation of cover-plates to floor-plates; based mainly on portions of l. ant. and l. post. rays. × 5 diam.

Fig. 6. A transection of the floor-plates, showing their relation to the interradials. The floor-plate on the left is viewed on its sutural surface, which bears the pore-canal. Based on the broken regions of ant. and r. ant. rays. × 5 diam.

Fig. 7. The hydropore. The adjacent regions of the floor-plates show the depression that receives the ends of the cover plates. × 10 diam.

Fig. 8. Parts of the floor-plates and cover-plates near the peristome, showing the accessory plates. × 10 diam.

Fig. 9. The periproct. × 8 diam.

Fig. 10. A section reconstructed along the line *a–b* in Figs. 1 and 3, showing the approximate thickness of the plates and the relations of the adapical hollow and lobes. Nat. size.

Fig. 11. Part of the thin, plated integument of the adapical face. The actual plates are not so clearly seen in this specimen as they are in some others (cf. Plate XIV). × 20 diam.

PLATE XI.

Edrioaster bigsbyi. Specimen B, from drawings made in 1899 by Mr. Gilbert C. Chubb.

Fig. 1. Adoral face, with the posterior interradius towards the observer. Cover-plates are preserved in all the rays, but are pressed into the grooves. × 2 diam.

Fig. 2. The adcentral region of the posterior interradius, showing the hydropore. × 10 diam.

PLATE XII.

Edrioaster levis. Holotype (Brit. Mus., E 15900). × 2 diam. These photographs were taken under water, so as to bring up the sutures and the fragments of plates, which are seen with much difficulty in the dry state.

Fig. 1. Adoral face. The small periproctals are seen depressed in the posterior interradius, next the observer.

Fig. 2. Adapical face. This shows the peripheral course of the grooves. The frame and the plated integument within it cannot be distinguished.

NOTE.—The explanation of Plates XIII and XIV will be given with those Plates in the next Number.

(*To be continued.*)

REVIEWS.

I.—AMERICAN PALÆONTOLOGY. A REVIEW.[1]

THE true founders of Palæontology, Lamarck and Cuvier, were interested in fossils simply as the relics of once living animals. Both compared their specimens with recent types; both from these comparisons drew philosophical conclusions, and established broad principles intended to apply to all animals, living or dead.

[1] Palæontology. By H. F. Osborn, with the co-operation of A. W. Grabau. *Encyclopædia Britannica*, 11th ed., pp. 579–91.

The Continuous Origin of certain Unit Characters as observed by a Palæontologist. By H. F. Osborn. Reprinted from the Harvey Lectures, ser. 1911–12, of the Harvey Society of the United States.

Cenozoic Mammal Horizons of Western North America. By H. F. Osborn, with Faunal Lists of the Tertiary Mammalia of the West by W. D. Matthew. U.S. Geol. Surv., Bull. 361, 1909.

The commonness of invertebrate fossils and their value as geological time markers, together with the apparent ease of determining them, caused their study to be pursued by men who had slight acquaintance with the structure of their recent allies, and led in the main to the description of great numbers of species and genera on characters chosen entirely at haphazard. This statement is perhaps too sweeping a charge to bring against the followers of a great science through a long period of its history, but the accused could urge with justice that they did what they could and that the method was legitimized by the geological importance of its results.

The study of invertebrate fossils, carried on as it was by men who were more interested in the geological aspect of their science than in its bearing on biology, was for years unaffected by the coming of the evolution theory. In 1866 Alpheus Hyatt published the first of that great series of papers which by introducing a new method, founded on the belief that "ontogeny repeats phylogeny", has revolutionized the whole point of view of invertebrate palæontologists, who are once again becoming biologists. It is unfortunate that Hyatt's work, containing as it does a philosophical conception of the first importance, the law of acceleration in development, is presented in such a way as to be nearly unintelligible. Following Hyatt, many authors — Hilgendorf, Waagen, Neumeyer, Branco, Mojsisovics, Buckman, Karpinsky, Jackson, and Beecher—have used his method and introduced others until there has been gradually built up a whole system of treatment of palæontological material, distinct in its philosophical basis from that appropriate to zoology in that it is wholly founded on the time sequence of the objects of its study, and depends for its success on the appreciation of those minute characters which represent the beginnings in evolution of the prominent features of later types.

Palæontology by these methods has reached conceptions of great importance to the science of biology, and will in time achieve its true place as the final arbiter of rival evolution theories, for it alone has access to those monumental records which are the sole contemporary evidence.

On its geological side the new palæontology is no less helpful than in its biological aspects; it has for the first time given a rational basis to the finer divisions of geological time, and has enabled its students to divide up some formations to an almost incredible extent.

The old palæontology, with its crude methods or rather lack of all method, and its dry-as-dust accumulation of 'facts', is doomed, and few will regret its passing.

Vertebrate Palæontology, owing to the character of its material, has always been pursued by men who were primarily comparative anatomists, and as such has always been a biological science. In consequence, it felt to the full the influence of Darwin's *Origin of Species*, the more so as that work was in part originally suggested by the fossil mammals of Patagonia.

From the time of A. Gaudry's classical account of the Miocene fauna of Pikermi, nearly all work on fossil vertebrates has been based on evolutionary ideas, and from the genius of its masters, Kowalevsky and Cope, early developed those methods of precise and detailed observation of fact followed by critical analysis, which, favoured by the discovery of abundant material, have led to the refinement of modern mammalian classification until it probably does represent with great accuracy the real relations of the animals with which it deals.

The expeditions of the American Museum, well directed and long-continued, have brought together so large an amount of accurately horizoned material of Titanotheres that the evolution of that group is known in very great detail; in fact, to a large extent a phylogenetic scheme is a real genealogical tree, and not merely a short method of indicating approximate relationships. Study of this unique material has led Professor H. F. Osborn to many generalizations, which are summed up in the works listed at the head of this review. The most important of these are—(1) that definite characters, such as horns, develop continuously by minute and almost imperceptible additions; (2) that in separate branches of the same stock, horns arrive independently on the same region of the skull.

These conclusions are of great biological importance; the ontogeny of the horns of cattle is so exactly similar to the phylogeny of those of Titanotheres as to render natural the conclusion that the horns of cattle have originated in the same way by continuous variation. Yet we know that hornedness is a mendelian allelomorph in cattle, so that this conclusion of Osborn's to a great extent cuts the ground from under the feet of de Vries and the 'mutationists'.

Another line of palæontological work which has been pursued with very great success by Professor Osborn is the study of the wanderings of mammals over the earth through Tertiary time, a study which depends for its success on detailed knowledge of the individual types dealt with, and on the accuracy of our knowledge of their periods. It may almost be said that this modern study is the invention of Professor Osborn; at any rate, he is its most successful exponent.

II.—Shan States, Burma.

Geology of the Northern Shan States. By T. H. D. La Touche. Mem. Geol. Surv. India, xxxix (2), 1913. pp. 380, xlii, with 27 plates and 3 coloured maps at 4 miles to 1 inch. Price 3 rupees or 4*s.*

"THE present memoir must be considered, not as a complete account of the Northern Shan States, but merely as a preliminary attempt to bring into order the observations made by my colleagues and myself: to furnish a basis, which I can only trust may be found to possess a certain degree of stability, on which future geologists may work; and to connect, as far as possible, the geology of this interesting tract with that of the surrounding regions. The area dealt with in these pages is almost twice the size of that of Wales, and it contains a sequence of rocks that for variety and complexity of structure may be compared with those that are found in that country, but with very few facilities for observation. It is covered for the most part with forest, or with grass so tall and dense that it is often impossible to force one's way through it; traversed by few roads, and those constructed at the least possible cost, and only driven through rock when it is absolutely necessary, while the same may be said of the only railway: while the mule tracks, the usual means of communication, are little better than footpaths. There are no quarries . . . for every house is built of timber or bamboo mats: and there are very few natural cliff-sections that enable one actually to see the superposition of the strata."

Such are the words of Mr. La Touche in his introduction to this most interesting memoir, and considering that he only spent some three and a half years in the area with Messrs. Datta, Pilgrim, and Coggin Brown he has certainly roughed into shape a large tract of country the stratigraphy of which will be of great use in solving many Asiatic problems in geology.

The author points out that this area is an ideal one for the traveller as compared with the Himalaya, for whereas the latter is a thousand miles from the sea-board and many days slow marches through the outer hills, to say nothing of the difficulties of reaching fossiliferous beds, in the Shan States the traveller can reach Maymyo in 428 miles by rail and from Mandalay can reach some of the most interesting localities in the day, and really study most of the important points in the geology in comfort by the railway. "Open park-like savannahs watered by clear rivers, whose waters afford fair sport to the angler, and whose banks furnish the most pleasant camping grounds." Peaceful, hospitable people, willing to help and harbour, affording new ground for the ethnologist, zoologist, and botanist, and with a climate superb for five months and even so superior to that of the plains that the Local Government has established its headquarters at Maymyo. Such is La Touche's description of the delights awaiting the explorer, and he does not fail also to specify particularly the nature of the problems awaiting such an adventurer from the geological point of view.

The country is, generally speaking, a plateau, much broken up and undulating, not unlike that of the 'downs' of southern England, the highest peak reaching 8,771 feet. It is mainly composed of a dolomitic limestone of Palæozoic age. This is assigned to Permo-Carboniferous-Devonian times and requires more leisured examination and collection before definite division. Lower beds include fossiliferous rocks belonging to Upper Silurian, Llandovery, and Ordovician, and unfossiliferous rocks are assigned to Cambrian and Archæan. Above the 'Plateau Limestone' come Rhætic, Jurassic, Pleistocene, and recent beds. The Tertiary, Cretaceous, and Triassic are, so far, wanting. Large series of fossils have been collected and partly described by Cowper Reed, Miss Healey, and C. Diener in *Palæontologica Indica,* and their richness in forms shows, as usual, the desirability of further collection in this area.

Antimony, poor lignitic coal, poor copper, fine rubies (previously well known through Barrington Brown and Judd), gold, iron, salt, and silver-lead also occur, and building-stones in abundance. An excellent geographical index and a subject index close the memoir.

The volume is written in an interesting and unofficial manner; full credit is given to previous observers, and their views together with those of his colleagues in the field seem fairly considered; and the author may be congratulated on a definite and progressive piece of work which will add to the already high reputation of the publications of the Indian Survey. The story of the difficulty of deciding on the age of the Napeng Beds is retold, and the final identification of *Avicula contorta* by Kossmat, associated with *Conocardium*, *Modiolopsis*, and *Palæoneilo*, with their final reference to the Rhætic, is of considerable interest. We have noticed but few errors, but E. T. should read R. B. Newton on p. 299. The plates of scenery and the maps are exceedingly good, and will be of the utmost value to travellers other than geological who visit what appears to be a fascinating and delightful country.

III.—Geological Survey of Canada.

"PORTIONS of Atlin District, British Columbia; with special reference to Lode Mining" are described by Mr. D. D. Cairnes (Memoir No. 37, Department of Mines, Ottawa, 1913). This mining district lies on the borders of Yukon territory in the north-western part of British Columbia. In 1898 it became known as a productive placer-gold camp, but the deposits are becoming slowly exhausted and more attention is now given to the lode-mining. Two specimens of quartz with free gold, from the Engineer Mines, are shown in a coloured plate which forms the frontispiece. The minerals of economic importance (other than placer gold) that are found in the Atlin district include gold-tellurium quartz veins, known only at the Engineer Mines and adjoining claims on the west side of Taku Arm. This is a broad water-channel which receives the main drainage, whence it flows ultimately into the Yukon River and Arctic Ocean. There are likewise gold-silver quartz veins, cupriferous silver-gold veins, silver-lead veins, copper and antimony veins; also indications of coal.

The particular area described in this memoir is that on the western side of Taku Arm, a rugged, bleak, and inhospitable land, but by no means devoid of grandeur, to judge by the many photographic views. Parts of the area are 3,300 feet or more above the Taku water-level, or 5,460 feet above the sea. The valleys are well wooded, and trees grow in some sheltered places up to 2,000 feet above the valley bottoms. The geological formations in this western area include the *Laberge Series* (Jura–Cretaceous), consisting of conglomerates, sandstones, greywackes, tuffs, shales, slates, and quartzites; the *Braeburn Limestones* (Carboniferous?); and the *Mt. Stevens Group* (pre-Devonian, and probably Lower Palæozoic), chiefly schistose amphibolites, crushed basic volcanic rocks, mica and hornblende gneisses, sericite schists, quartzites, and limestones. There are also the *Chieftain Hill volcanics*, chiefly andesites, andesitic tuffs, and breccias (probably Tertiary); and the *Coast Range intrusives*, chiefly grano-diorites (Jurassic?). Quaternary deposits comprise gravels, sands, boulder-clays, silts, 'muck,' and peat.

The ores at the Engineer Mines occur in veins mainly in the Jura-Cretaceous. Some compound veins are more than two hundred feet thick, the chief metallic mineral being native gold. Gold-silver quartz veins are the most widely distributed, and they occur in the *Mt. Stevens Group* and in the volcanic and intrusive rocks.

Some formations other than those mentioned occur over limited areas on the eastern side of Taku Arm, and all are described. The origin of the ore deposits is also discussed. There are views of mines and mine-works, and a small colour-printed geological map.

IV.—Outlines of Mineralogy for Geological Students. By Grenville A. J. Cole. 8vo; pp. 339 + vii, with 124 figures in the text. London: Longmans, Green & Co., 1913. Price 5*s*. net.

THE need of a good elementary textbook of mineralogy, which meets the requirements of geological students, must be felt by many. Professor Cole has set himself to supply this need and has successfully accomplished a difficult task. His large experience in the training of geologists has enabled him to anticipate their difficulties and to present theories and facts in a most lucid way, omitting nothing that is essential to a clear presentation of the subject.

The treatment of the physical and chemical properties of minerals is clear and calls for little comment. The descriptions of the use of Walker's Balance and of Sollas's Diffusion Column for the determination of specific gravity will both be found useful for practical work.

The chapters on crystallography are necessarily brief, but are well written. The seven crystallographic systems are taken in order of increasing symmetry, with the hexagonal and trigonal systems last. Exception may be taken to the use of the Bravais-Miller indices for the trigonal system, as this presents serious disadvantages. The advantages of using Millerian indices for this system are many, as pointed out recently by Dr. Tutton, but Professor Cole urges that "it presents a difficulty in the abolition of the vertical crystallographic axis; moreover, the notation of the individual crystal-faces . . . gives symbols absolutely different from those of all the other systems". Surely this is not the case. The projection of a trigonal crystal on Miller's axes gives indices for all the faces which are exactly similar to those for the corresponding faces of a cubic crystal, projected with one triad axis in the vertical position.

In the description of optical characters, due emphasis is laid on the use of convergent light in the determination of minerals. A useful innovation is the reproduction of Siethoff's diagram for the representation of the isogyres of a biaxial crystal.

The chemical methods most useful in mineral determinations are described, and the special tests for individual minerals are given in the descriptive part of the book.

The chapters dealing with descriptive mineralogy are preceded by an interesting discussion on classification and nomenclature. The classification has been chosen to meet the demands of students of chemistry, mining, and geology, and is one which the author has found to work admirably in practice. It is based on Mendeléeff's periodic classification of elements. Compounds are grouped together according to the bases, and not by their acid radicles; elements are treated in the chemical groups in which they fall. Thus in group viii come minerals containing iron, nickel, and cobalt; rutile, zircon, and cassiterite fall together in group iv, sodium and potassium compounds in group i, and so on. The groups are taken in inverse order, commencing with group viii, and the silicates are taken last as a special division.

In the treatment of the silicates the optical properties and means for determining the minerals in thin sections are described.

An account of the use of Szabo's flame-reactions for the determination of felspars, with simple apparatus for its application, is very welcome. It is in this part of the book that the author has shown himself fully alive to the points which are most likely to perplex the student. In describing the measurement of the extinction directions in augite a notable point is made. In most textbook diagrams showing the extinction directions of augite in the plane of symmetry the figure is bounded by the faces (100) and (001), whereas in rock-sections the bounding edges are usually the traces of (110) and ($\bar{1}11$); thus the extinctions must be measured towards the upper acute angle in rock-sections, but towards the upper obtuse angle of the diagrams. It is unfortunate that a misprint has crept in here; the face given as (111) on p. 305 should obviously be ($\bar{1}11$).

The book is full of references to recent mineralogical work, and is thoroughly up to date. The student of geology who works through this book should be able to turn to petrology with a real knowledge of minerals and their optical properties, and should be in a position to grasp the reasons for the phenomena which he observes in thin sections. It is for this reason that the silicates have been reserved to the end. To quote Professor Cole: "The geologist . . . reaches the silicates as a sort of climax. His most difficult work comes last, and the fact that by this time he is familiar with a variety of minerals that he has handled, and with specimens where crystalline form is readily apparent, will prevent him from regarding the earth as composed of bodies presented to his eye as thin sections under the microscope."

W. C. S.

V.—Physical Chemistry and Petrology.

Notes on some recent work at the Geophysical Laboratory of the Carnegie Institution of Washington.

1. "The General Principles underlying Metamorphic Processes." By J. Johnston and P. Niggli. Journal of Geology, Chicago, vol. xxi, pp. 481–516, 588–624, 1913.

This paper discusses the validity, limitations, and relative importance of such physico-chemical principles as are operative in metamorphic processes. The term metamorphism is used in a restricted sense, being limited to those cases in which "the effects produced by the alterations determine completely the character of the rock mass". The agents concerned in such cases include temperature, uniform and non-uniform pressure, mass-action, the phase rule, and metamorphism with addition of material. The general effects produced by these agents are discussed in the light of the most recent researches, for many of which the authors themselves are responsible.

Great emphasis is laid on the distinction between uniform pressure and non-uniform pressure, or 'stress'. It is shown that, for most minerals, under the influence of 'stress' the melting-point is lowered and the solubility increased, but under uniform pressure the melting-point is raised while solubility is not appreciably affected. Further, the condition of uniform pressure is rarely attained in practice, and its effects are much less important than those of 'stress'.

The general character of the processes brought about by the operation of the various factors effective in metamorphism can be predicted, but there is a general lack of accurate quantitative physical data for rock-forming minerals. The utmost caution must be used in attempting to apply to rocks the experimental results obtained for simple systems. Complications frequently arise owing to such factors as the slow rate of reaction, the occurrence of metastable forms or the attainment of positions of false equilibrium. Such complications may have particularly important effects on the application of the phase rule, and especially on the use of transformation points between allotropic modifications of rock-forming minerals as fixed points on a geological scale of temperature.

2. "The Hydrothermal Formation of Silicates: A Review." By G. W. Morey and P. Niggli. Journ. Amer. Chem. Soc., vol. xxxv, pp. 1086–1130, 1913.

Many rock-forming minerals have been synthesized by heating their components in the presence of water in closed steel vessels, but such hydrothermal syntheses have rarely been investigated quantitatively. The authors have reviewed the work of the earlier experimenters and have compiled a detailed bibliography, giving a brief synopsis of each paper, and a list of minerals obtained by hydrothermal methods. This bibliography is invaluable and should serve as a basis for future research in this field.

Discussing the theoretical principles of these syntheses, the authors show that all hydrothermal processes are primarily crystallizations from aqueous solutions, and, as such, they may be treated on lines similar to those followed by van't Hoff in his researches on oceanic salt deposits. The relations are necessarily extremely complicated, but it has been found possible to indicate the main points to which attention must be directed in quantitative work.

3. "The Phenomena of Equilibria between Silica and the Alkali-Carbonates." By P. Niggli. Journ. Amer. Chem. Soc., vol. xxxv, pp. 1693–1727, 1913.

The existence in rock-magmas of volatile constituents and their combination with involatile constituents is well known, but the conditions which control such interactions is little understood. Much light is thrown on this problem by the investigation of the phenomena of equilibrium between alkali-oxides, silica, and carbon dioxide. The system has been studied for temperatures between 900° and 1,000° C.

in a current of carbon dioxide. The nature of the reactions are described for the oxides of sodium, potassium, and lithium, but for the latter the investigation is incomplete. The optical properties of silicates of these elements are given.

It is found that, "within the temperature range investigated, there may be in melts a large proportion of carbonate in equilibrium with the other components." In the discussion of the relations which hold for such systems as these, the solubility of the gas in the liquid phase must be taken into account.

The authors are now investigating some systems analogous to those discussed in this paper, in which the oxides TiO_2 and Al_2O_3 are introduced. The ultimate results of this work must lead to a clear understanding of the action of 'gas-mineralizers', and will indicate the conditions necessary for the crystallization from magmas of minerals containing volatile constituents such as water, fluorine, or carbon dioxide.

VI.—Stanford's Geological Atlas of Great Britain and Ireland with Plates of Characteristic Fossils. Preceded by descriptions of the geological structure of Great Britain and Ireland and their counties, of the Channel Islands, and of the features observable along the principal lines of railway. By Horace B. Woodward, F.R.S., F.G.S. 3rd edition. 8vo; pp. xii, 214. London: Edward Stanford, Ltd., 1914. Price 12*s.* 10*d.* post free.

With a geologically coloured map of Great Britain (frontispiece); (1) a folding index (coloured) to geological maps, giving also to each formation the names of the principal organic remains or fossils; (2) 18 sections and views in the text; (3) 58 county and other maps, geologically coloured; (4) 16 plates of fossils.

IT will interest his numerous friends, geologists, students, and others to learn that this third edition was the very last piece of literary and geological work upon which the author was engaged only a few days before the internal malady, from which he had so long suffered, compelled him to lay down his active pen, which his clever, fertile brain could no longer direct. Writing in pencil, two days before the end was reached, he said of this book: "In a third edition it is only necessary to call attention to the chief additions, etc., thus: the present edition has been amplified by an account of the geological features of the Channel Islands, and the writer is indebted to Dr. J. S. Flett for some notes on rocks, personally collected in Jersey. Further descriptions have been given of features observable along railways in England and Wales. A number of small additions and corrections have been made in the text, and the acreage of counties has been revised, the areas given being land with inland water *exclusive* of tidal water and foreshore. The maps have been revised, notably in the case of the Silurian of Central Wales, as determined by Professor O. T. Jones; new railways and further names of places have been inserted."

A small photographic supplement to this Atlas has been prepared, with the co-operation of Miss Hilda D. Sharpe, which makes a further interesting illustrated addition to the work.

VII.—New Serials.

THERE is quite a crop of new serials devoted to geology and allied sciences. The first is *Verhandelingen van het Geologisch-Mijnbouwkundig Genootschap voor Nederland en Koloniën*, a quarto published at 's Gravenhage, of which four parts appeared in 1912–13. These contain papers by Waterschoot van der Gracht on North Brabant Coal-field; a most valuable bibliography of all the Netherland East Indies by R. D. M. Verbeek, arranged in islands; *Ursus etruscus* from Tegelen by E. T. Newton; Red Flinty Clay by J. Lorié and H. G. Jonker; and Jura Erratics from Kloosterholt by J. F. Steenhuis.

In the second, *Memorie dell' Istituto Geologico della R. Università di Padova*, vol. i, 1912 (edited by Giorgio Dal Piaz), large quarto, Padova, we have papers by the editor on the Geotectonics of the Brenta and the Lake of Santa Croce, and on the Bathonian fauna of Monte Pestello; by R. Fabiani on the type of *Crocodilus vicetinus*, Lioy; by G. Stefanini on the Miocene Mammals of Venetia; and by A. De Toni on the Brachiopoda of the *Ceratites trinodosus* zone of Monte Rite.

The third, entitled *Monographias do Serviço Geologico e Mineralogico do Brasil*, vol. i, 1913, Rio de Janeiro (Ministerio de Agricultura), is also a quarto and is entirely occupied by J. M. Clarke's Fosseis Devonianos do Parana, a valuable and exhaustive paper illustrated by twenty-seven excellent plates of Trilobites, Molluscs, Brachiopods, and Echinoderms, with text in Portuguese and English.[1]

The fourth new serial hails from Canada and is called *Bulletin of the Victoria Memorial Museum*, No. 1, and appears to be an issue from the Geological Survey. It is an octavo, is dated October 23, 1913, and is published at Ottawa. This contains many papers by Bather, Lambe, Raymond, Wilson, and Johnston on geological subjects, and by others on zoology, botany, and anthropology.

VIII.—Brief Notices.

1. Underground Water for Commercial Purposes.—Under this title Dr. Frank L. Rector, of New York, has written a compact and useful handbook of 98 pages (London, Chapman & Hall, 1913, price 4*s*. 6*d*. net). Although written round American points it is equally applicable to this country. Beginning with the source of water, the author deals with ground water, distribution and properties, springs, wells and construction, watersheds, mineral waters, chemical and bacteriological examination, and appends useful rules and tables of capacities of tanks, pipes, cylindrical vessels, pressures per square inch, and expansion at different temperatures. A short bibliography and a clear index close the volume.

2. Palæontology for 1912.—The Zoological Record issued by the Zoological Society of London has reached its 49th volume. It is not generally known that this valuable publication includes palæontological as well as recent zoological papers and is of the greatest value

[1] A large number of the illustrations are reproduced in Bull. 164, New York State Museum, 1913, for comparison with New York forms.

to geologists. Compiled by specialists in all its branches, it should always be referred to by anyone engaged in work on the fossil forms. The separate sections, Mammalia, Aves, Mollusca, etc., can be separately obtained from the Zoological Society at a reasonable price, and as the contents of the papers are indexed into groups one can easily find the forms upon which one is working.

3. Foraminifera.—Frederick Chapman describes numerous Foraminifera from deep borings in the Mallee, about 6 miles east of the South Australian boundary. He does not at present state the age, but the forms appear to be of low Tertiary age. Other groups are described and figured, and perhaps that of most interest is an *Antedon*, new, but referred by comparison to a Port Jackson form. (Proc. Roy. Soc. Victoria, xxvii, pt. i.).

Heron-Allen and Earland write on the Foraminifera in their rôle as world-builders; a review of the Foraminiferous limestones and other rocks of the Eastern and Western Hemispheres (Journ. Quekett Micro. Soc., xii). This is a general paper, but brings together a good deal of information otherwise buried in various publications.

Rufus M. Bagg, on the Pliocene and Pleistocene Foraminifera from Southern California (Dept. of Interior, U.S. Geol. Survey, Bull. 513, 92 pp. and 28 pls.), renders available a large number of forms for comparison, all carefully worked out and illustrated. Very little is new, but such monographs are of considerably more than local interest.

4. *Spongites saxonicus.*—Dettmer (Neues Jahrbuch, 1912 (2), 114–26) discusses the various forms known as *Spongites saxonicus*, Geinitz, from the Chalk. He compares them with Foraminifera, worm-casts, and fucoid stems, and figures various specimens of each kind, suggesting that these curious remains may have several origins. Similar forms are fairly abundant in our own Chalk, and readers of the Geological Magazine will recall Dr. Bather's recent communication on worm-casts from the English Chalk (1911, pp. 481, 549) preserved in the British Museum.[1]

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *January* 7, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read—

1. "The Ordovician and Silurian Rocks of the Lough Nafooey Area (County Galway)." By Charles Irving Gardiner, M.A., F.G.S., and Sidney Hugh Reynolds, M.A., F.G.S., Professor of Geology in the University of Bristol.

The Lough Nafooey area is a direct continuation of the Kilbride area (described in 1912), from which it is separated by the Finny River. It forms a ridge about 4 miles long, which reaches its highest point (1,678 feet) at Curraghrevagh Mountain, and slopes steeply down to Lough Nafooey on the north, and more gradually to Glen Trague on the south.

[1] See also T. McK. Hughes, on *Spongia paradoxica*, Geol. Mag. 1884, p. 185.

The rocks are of Arenig, Llandeilo, and Silurian age, together with intrusive felsites, bostonites, labradorite-porphyrites, and dolerites.

The Llandeilo rocks (Mweelrea Grits and Conglomerates) are mainly confined to the low-lying ground along the shore of Lough Nafooey, and have yielded no fossils. They dip at a high angle off the Arenig rocks, which extend in a band from a third to half a mile wide from end to end of the area. The Arenig rocks consist in the main, as at Kilbride, of spilite lavas associated with coarse breccias, and with bands and patches of chert, in which at two points Radiolaria were found. The Lough Nafooey area agrees with those of Glensaul and Tourmakeady in the presence of limestone breccias which were absent at Kilbride. Unfortunately, no graptolites were found in the Arenig rocks of Lough Nafooey. Pillow-lavas show a splendid development, especially near the top of Bencorragh. Silurian rocks form the whole southern half of the area, including the highest point, Benbeg (1,788 feet). They are very highly inclined, being (for much of their extent) vertical or sometimes slightly overfolded. They include representatives of the Llandovery, Tarannon, and Wenlock formations, and exhibit the same general succession as at Kilbride, although the relative thicknesses of the several bands are not the same. The occurrence of *Monograptus galaensis* on the north-eastern slopes of Benbeg confirms the field evidence as to the Tarannon age of certain grey flags. The Wenlock Beds, as at Kilbride, are represented by thick grits (Doon Rock Grits), a thickness of over 800 feet being seen. Of the intrusive rocks, felsites are not so prominent as at Kilbride, and, while at that locality they are always associated with Arenig rocks, at Lough Nafooey some are clearly of later date—occurring in the Llandeilo formation, or along the line of junction of the Llandeilo and other rocks.

The bostonite sill seen at the base of the Silurian rocks at Kilbride extends almost continuously throughout the Lough Nafooey area, but is much reduced in thickness. Other small intrusions of bostonite occur in addition to this sill, which, as at Kilbride, is associated in places with labradorite-porphyrite. The prevalence of mica-dolerite intrusions in the purple shale (Tarannon) is a noteworthy feature.

The paper concludes with a table comparing the rocks of the Lough Nafooey area, on the one hand with those of Kilbride, and on the other with those of the Killary district described by Mr. R. G. Carruthers and Mr. H. B. Maufe.

2. "The Geology of the St. Tudwal's Peninsula (Carnarvonshire)." By Tressilian Charles Nicholas, B.A., F.G.S.

The St. Tudwal's Peninsula is situated at the south-eastern extremity of South-West Carnarvonshire (Lleyn), and forms the north-western limit of Cardigan Bay; it is underlain by Cambrian and Ordovician rocks. In the southern part of the peninsula the structure is relatively simple, and the succession very plainly displayed in numerous cliff-sections; Cambrian rocks very similar in character to those of Merionethshire form most of the coast, but the interior is mainly occupied by Arenig beds, which rest with a marked unconformity on every local member of the Cambrian in turn. The latter have fortunately escaped cleavage, and some mudstones in the midst of the series have yielded a number of fossils belonging to the zone of *Paradoxides hicksi.* The *P. davidis* zone appears to be absent, as the result of a slight unconformity.

This southern area of relatively simple structure is separated by an overthrust of considerable magnitude from a more northern area in which members of the Tremadoc, Arenig, and Llandeilo Series have been recognized, but in which the rocks are highly crushed, faulted, and disturbed, and the relations between the beds are far from clear.

The general succession is—

South of the Thrust.		*North of the Thrust.*
	LLANDEILO.	Hen-dy-Capel Mudstones. (Zone of *Nemagraptus gracilis.*)
	LLANVIRN.	
Llanengan Mudstones. Tudwal Sandstones and Grits. (Zone of *Didymograptus extensus.*)	ARENIG.	Benar Beds. (Zone of *Didymograptus extensus?*) Probable unconformity.
	TREMADOC.	Abersoch Beds.
Great unconformity.		
	DOLGELLY.	
Ffestiniog Beds. (Only in East St. Tudwal's Island.)	FFESTINIOG.	
Maentwrog Beds. Probable unconformity.	MAENTWROG.	
Nant-pig Mudstones.	MENEVIAN (of Merionethshire).	
Caered Mudstones and Flags. Cilan Grits. Mulfran or Manganese Beds. Hell's Mouth Grits. Base not seen.	HARLECH GRITS (of Merionethshire), (in part).	

Pisolitic iron-ore is well developed in the district, and occurs chiefly in the Landeilo Beds along the line of the overthrust; it is regarded as of sedimentary origin. The glacial geology is only briefly dealt with; but evidence is presented to show that, during the last phase of glaciation, the ice was moving across the peninsula in a westerly direction out of Cardigan Bay.

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2. *January* 21, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "Geology of the Country round Huntly (Aberdeenshire)." By William Robert Watt, M.A., B.Sc., F.G.S.

In this area two distinct series of rocks can be distinguished—a foliated and a non-foliated series. In the former occur rocks originally sedimentary and others originally igneous. In the non-foliated series, which is wholly of igneous origin, three main intrusions occur:—

(1) The earliest and most extensive is a norite with, as modifications due to differentiation, olivine gabbros, troctolites, and 'picrites'.

(2) Into this is intruded the heterogeneous mass known as the Central Intrusion, which consists of three main types with no distinct boundaries—

(*a*) At the margin occurs a fine-grained norite with pronounced mineral banding. Nearer the centre of the mass is met (*b*) a biotite-plagioclase rock; and the centre itself is composed of (*c*) a garnet-monzonite.

(3) The third large intrusion is the Carvichen Granitite, composed chiefly of quartz, microcline, and biotite.

Each of these masses produces some contact-alteration in the surrounding foliated or non-foliated rocks. Where the Central Intrusion or the Carvichen Granitite is intruded into the earlier norite, a norite containing cordierite is produced. The original norite, by absorption of sediment, produces also along its margin a cordierite-norite. Similar types have been described by Professor A. Lacroix and Mr. A. N. Winchell.

Both types of cordierite-norite tend to pass into a rock composed essentially of plagioclase, biotite, and garnet; and this change, with the gradual destruction of the hypersthene, can be seen in various stages.

2. "The Glacial Geology of East Lancashire." By Albert Jowett, D.Sc., F.G.S.

The area dealt with comprises the western slopes of the Pennines, from Boulsworth Hill to Blackstone Edge, and their westerly offshoot, the Rossendale highland, which separates the basin of the Ribble from that of the Irwell and Mersey.

Three types of drift have been recognized—

(1) Local drift, consisting of materials which can be found in situ in the neighbourhood, chiefly Coal-measures and Millstone Grit.
(2) Ribblesdale drift with Carboniferous Limestone, chert, and Silurian grit, as well as local material.
(3) North-western drift, which, in addition to any or all of the above-mentioned constituents, contains igneous rocks from the Lake District and the south-west of Scotland.

The distribution of the drift and the evidence of striated rock-surfaces suggest the invasion of this area by an ice-sheet which reached up to the Pennine watershed, and projected ice-lobes across it through the gaps at Widdop, Gorple, Cliviger, and Walsden.

A small unglaciated region occurs a few miles south-west of Todmorden.

In the north-eastern portion of the area the general direction of ice-movement was from north to south; in the west it was from north-north-west to south-south-east, but on the south of the Rossendale highland the direction of flow curved round towards the east-north-east, and ultimately, in the neighbourhood of Rochdale, towards the north.

The local drift is believed to have been produced by the overlapping of 200 feet or so of clean ice, which formed the upper portion of the ice-sheet, beyond the limits reached by the ice containing erratics. No evidence of local glaciation has been found.

The limit of the north-western drift rises at the rate of about

4 feet per mile from Blackstone Edge towards the Irish Sea; therefore, when at its maximum the ice-sheet was probably over 2,000 feet above present sea-level in the middle of the Irish Sea in this latitude.

Extensive systems of glacier-lakes and drainage-channels were produced on the retreat of the ice, and for some time the drainage on the west of the Pennines in the Ribble and Irwell basins escaped eastwards into the Yorkshire Calder.

It is probable that the north-western ice arrived in this area later, and disappeared earlier, than the Ribblesdale ice.

Some local fluctuations in the ice-sheet occurred, but there is no evidence for more than one Glacial period.

CORRESPONDENCE.

ROCK-SOIL AND PLANT DISTRIBUTION.

Sir,—Mr. A. R. Horwood, in his article under the above heading in the January number of the Geological Magazine, makes certain statements in regard to the distribution of plants, with special reference to Derbyshire, which must be accepted with caution.

To deal only with the fourteen plants which he names as being "so strong [in] their attachment to lime soils and their absence so well marked upon others", that limestone could be mapped, even if only one or two of them occurred where no exposures were available, I find in Linton's *Flora of Derbyshire* (1903) that one only (*Galium asperum*) is peculiar to limestone; seven are characteristic of that formation, but not peculiar to it; and the remaining six appear to occur indiscriminately on all the formations in the county.

I happen to live in Derbyshire, in the immediate neighbourhood of Carboniferous Limestone, Limestone Shales, Millstone Grits, and Lower Coal-measures, and, from my own observation, several of Mr. Horwood's fourteen limestone plants grow frequently on other formations. Specially may be mentioned *Reseda luteola*, *Geranium lucidum*, and *Habenaria viridis*.

As an instance of the difficulty of defining with precision the soil-distribution of plants, I may mention that I have for years regarded *Pteris aquilina* as a limestone-hating plant. Here and there patches of it occur in a limestone district, as in the Via Gellia, near Cromford, but hitherto, with one exception, in all such instances the soil has proved to be either an isolated patch of drift or a clay derived from the decomposition of toadstone. The exception occurred last autumn when, in the same neighbourhood, I observed *Pteris aquilina* growing over an area of, perhaps, half an acre on an undoubted limestone outcrop. Further examination revealed that the soil was derived from the weathering of a *dolomitized* limestone, the chemical composition of which seems to have reconciled the fern to its situation.

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

Brook Cottage,
Fritchley, Derbyshire.
February 10, 1914.

OBITUARY.

GEHEIMRATH PROF. KARL HARRY FERDINAND ROSENBUSCH.

BORN 1836. DIED JANUARY 20, 1914.

ALTHOUGH the subject of this notice was generally known in this country under the name of *Heinrich* Rosenbusch, I can find no authority for the use of this Christian name. His official designation was as given above, while in all his published writings and private letters, down to the year 1900, he subscribed himself H. Rosenbusch, after that date using the name 'Harry' only.

The distinguished petrographer was born at Einbeck in Hanover in the year 1836, and was educated at the gymnasium of Hildesheim and the Universities of Göttingen, Freiburg, and Heidelberg, acquiring a taste for mineralogical studies at the last-mentioned seat of learning under Professor Blum. Before taking his doctor's degree, however, Rosenbusch accepted a post as tutor in a Portuguese family and proceeded to South America, and it was at this time probably that he made that wide acquaintance with foreign languages by which he was so greatly distinguished in after life. In 1868 he was back again in Freiburg, where he took his degree and in the following year became a privat-docent.

Rosenbusch's residence in Freiburg had very important results not only in his own career but in the development of petrographical science. The Professor of Mineralogy in the University of Freiburg at that day was Heinrich Fischer, who had not only made himself acquainted with all that had been previously done in applying the microscope to the study of rocks, but had brought together a large collection of rock-sections upon which he had based his *Kritische mikroskopisch-mineralogische Studien* and his well-known treatise on Nephrite and Jade. These sections and Fischer's extensive library were placed at Rosenbusch's service, as he gratefully acknowledged, and soon the enthusiastic pupil was able to carry the work much farther than the master had done. Rosenbusch recognized the important fact that the exact determination of the minerals seen in a rock-section must be based on rigid optical methods, and he set to work to make the improvements in the microscope which would enable such methods to be employed. In 1873 Rosenbusch's epoch-making work on the rock-forming minerals made its appearance, to be followed in 1877 by his great treatise on rocks. Of the far-reaching influence of these works and of the successive editions of them it is unnecessary to speak—their praise is in all the schools.

After the war of 1870 the German Imperial Government determined to prepare a geological map of Alsace and Lorraine, and Rosenbusch was appointed a member of the Survey and at the same time extra-ordinary professor in the University of Strasburg; this led to the publication of his well-known memoir on the Andlau granite and the contact metamorphism produced by its extrusion.

But in 1878, by his appointment to the full professorship of Geology at Heidelberg, Rosenbusch reached the goal of his ambitions, and soon founded his famous "Mineralogisches-geologisches Institut". Here during the following twenty-eight years he attracted successive generations of enthusiastic students from all countries, perfecting his methods and applying them in a number of petrographical memoirs, but doing still more important work by his example and influence on the labours of his devoted followers.

In 1906, upon reaching the age of 70, Rosenbusch retired from his professorship, the event being made the occasion of the publication of a 'Festschrift', in which his students from all parts of the world published original memoirs devoted to the science they had learned from their great master. On January 20, 1914, Rosenbusch passed away, after a short and severe illness, leaving a widow but no children.

No notice of Rosenbusch would be complete without a reference to the amiability and charm of his personality. He was a born teacher and inspired the strongest feelings of affection in his pupils. They loved to dwell in after years on his conversations as he made the round of his laboratory, his enthusiasm when, with lighted cigar, he demonstrated the existence of carbon dioxide in cavities of quartz, and his constant insistence that no determination of a mineral should be considered settled till every optical test had been applied. By his scientific contemporaries in all countries he was equally esteemed and loved. Ever ready to exchange specimens, sections, and ideas, he was modest and gentle in expressing dissentient views, and friendly and generous in agreement and appreciation of the work of others. Rosenbusch has left a great and enduring mark upon the geological science of the nineteenth century.

John W. Judd.

ALBERT C. L. G GÜNTHER,
M.A., M.D., Ph.D., LL.D., F.R.S., F.L.S., F.Z.S.

Born October 3, 1830. Died February 1, 1914.

Another eminent naturalist has just passed away, an old friend and colleague of the writer for many years in the British Museum, and for half a century the highest authority in this country on Ichthyology.

Albert Charles Lewis Gotthilf Günther was the son of Frederick Gotthilf Günther, of Möhringen, and a descendant of the first Duke of Würtemberg, the founder of the University of Tübingen. Here young Günther, as founder's kin, was entered and received a free education, taking the Ph.D. degree in 1852. He next worked at the University of Bonn, and at Berlin, under Johannes Müller. In 1853 he published his first paper, on the fishes of the River Neckar. He qualified as a physician and surgeon, doing part of his work at St. Bartholomew's Hospital in London, and taking the degree of M.D. at Tübingen in 1862.

In 1855 he was engaged at the British Museum to prepare Catalogues of Fishes and Reptiles, under Dr. J. E. Gray, and after eight years special work he was appointed an Assistant in 1864, and succeeded Dr. Gray as Keeper of Zoology in 1875, a post which he retained until 1895, when he retired on a pension. While in the Museum he prepared ten volumes of the Catalogue upon Colubrine Snakes, Batrachia, and Fishes. He also published "The Reptiles of British India", "Shore Fish", "Deep Sea Fishes", and "Pelagic Fishes" in the *Challenger* Reports; and an "Introduction to the Study of Fishes". In 1880 he took charge of the removal of the Zoological Collections from the British Museum, Bloomsbury, to the New Natural History Museum in Cromwell Road.

In 1864 Dr. Günther founded the *Zoological Record*,[1] an annual publication. He was also one of the editors for more than thirty years of the *Annals and Magazine of Natural History*. So long ago as September, 1864, Dr. Günther contributed a paper on "A New Fossil Fish from the Lower Chalk, *Plinthophorus robustus*, Gthr." (Geol. Mag., Vol. I, pp. 114–18, Pl. VI, 1864), and in 1876 "On the Fish Fauna of the Tertiary Deposits of the Highlands of Padang, Sumatra" (Geol. Mag., Dec. II, Vol. III, pp. 433–40, Pls. XV–XIX).

Dr. Günther was elected to the Royal Society in 1867, became a Vice-President 1875–6, and received a Royal Medal in 1878. He was President of Biology, British Association, 1880; President of the Linnæan Society 1898–1901, F.Z.S. in 1862, and V.P.Z.S. 1874–1905.

He married, first, in 1868, Roberta Macintosh, of St. Andrews (who died in 1869); second, 1879, Theodora Dawrish, daughter of Henry Holman Drake, of Fowey, Cornwall, who survives him. His eldest son, Mr. R. T. Günther, is a Fellow and Tutor of Magdalen College, Oxford, and is distinguished as a zoologist, geographer, and antiquarian.

Dr. Günther died on February 1, 1914, in his 84th year at 2 Lichfield Road, Kew Gardens, leaving behind him a splendid record of biological work accomplished during his long and strenuous life.

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

Born August 20, 1848. Died February 6, 1914.

(WITH A PORTRAIT.)

When death severs a friendship of forty years it is difficult to form a true estimate of the friend's lifework, and this is specially difficult in the case of H. B. Woodward, whose life was more generously spent in aiding others than in those original researches which might permanently establish his reputation.

Born in London in 1848, the son of Dr. S. P. Woodward, F.G.S.,[2] of the Department of Geology in the British Museum (1848–65), Horace was educated in a private school, and in 1863 was appointed assistant to the Secretary, Mr. H. M. Jenkins, at the Geological Society, Somerset House. This position he did not hold for long, being appointed in 1867, at the age of 19, an Assistant Geologist on the Geological Survey, under Sir Roderick Murchison. The greater part

[1] Still continued by a Committee of the Zoological Society.

[2] See Obituary, Geol. Mag., August, 1865, pp. 383–4.

of his life was thus spent in official harness, for he did not retire until the end of 1908.

His Survey work was so varied that it is difficult to give a connected account of it. In his early life he worked much under Mr. H. W. Bristow, F.R.S., in Somerset and various other districts. He took part in the first Drift Survey of the London area; but he was before long transferred to the disturbed rocks of the Somersetshire Coal-field. Then he was engaged on the Palæozoic and Secondary rocks of Devon and Somerset; this varied experience assisting him greatly in the preparation of his very useful *Geology of England and Wales.*[1] In Devon the writer joined him, and he has reason to remember Horace Woodward's kind help and patience with the inexperienced; he never tired of assisting those who worked with him, and this was a most striking characteristic till the end of his life.

Much of this early work by Horace Woodward is unpublished, or has only lately appeared, for after several years in Devon, Somerset, and Dorset, he was transferred to Norfolk and Norwich, leaving the Devon maps to be completed by Mr. W. A. E. Ussher and others. He was, however, the chief author of the memoir on the East Somerset and Bristol Coal-fields, published in 1876.

In Norwich he spent a good many years, probably some of the happiest in his life. He was in the native city of his grandfather, his father, and uncles, and he liked to recall the connexion of his family with the county, for his grandfather, Samuel Woodward, had been one of the earliest writers on that country, and had published the *Geology of Norfolk* in 1833. Here also, after his recovery from a serious illness which had interfered with his work for some time, he was again able thoroughly to enjoy the open-air life. He was in his element leading a geological excursion, presiding at some meeting for popularizing science, or discussing geological questions with his colleagues, several of whom were then working in the eastern counties. The principal result of his stay in Norfolk is seen in the accurate geological maps, and in his *Geology of Norwich, of Fakenham, Wells, and Holt*, and other memoirs; but in his leisure he was already collecting material for a second edition of his valuable work, the *Geology of England and Wales.*[2]

During his residence in Norwich he was President of the Norwich Science Gossip Club and of the Norwich Geological Society. At a later period he was President of the Norfolk Naturalists' Society.

Among his other publications he wrote *Memorials of* (*Rev.*) *John Gunn*, formerly Rector of Irstead (1891), whose remarkable collection of Forest Bed Pleistocene Mammalia from the Norfolk coast now adorn the Norwich Castle Museum.

His next extensive piece of work was the writing of three volumes of a memoir on the *Jurassic Rocks of Britain*, which necessitated several years spent in visiting the numerous exposures; but this work was much hindered by official calls, which every year became more pressing. He was able, however, at intervals, after 1892, to aid in the mapping of the Jurassic strata in Scotland, including Skye and

[1] 8vo, Longmans (1876), pp. xx, 476.
[2] 1887, Geo. Philip and Son, 8vo, pp. 16, 670, with maps and illustrations.

Raasay, and was the first to point out the presence in Raasay of a bed of iron-ore, which is now recognized to be of high commercial value.

In 1893 he was appointed, on the death of Mr. William Topley, to take charge of the Geological Survey Office in Jermyn Street, London, under Sir Archibald Geikie, and from that time the endless duties of inspection, editing, and official correspondence left him little leisure for original work. In time Horace Woodward's responsible position was recognized and he became Assistant Director for England and Wales; but this led to no lessening of the amount of routine work. In his spare time he still worked hard, and to him we owe the History of the Geological Society of London prepared for the Centenary of 1907 (8vo, pp. xx, 336). Besides contributing to the Scottish memoir on Glenelg, etc. (1910), he took the principal share in the Water-supply memoirs of Lincolnshire (1904) and Bedfordshire and North Hants (1909). He also wrote a memoir on the London district (1909), and one on soils and subsoils which passed through a second edition (1906).

Mr. Horace Woodward was an Honorary Member of the Yorkshire Philosophical Society, the Cotteswold Naturalists' Field Club, and the Essex Field Club. He was elected a Fellow of the Geological Society of London, 1868; he served on the Council eleven years, and was a Vice-President 1904–6. He was elected a Fellow of the Royal Society in 1896.

The value of his work was recognized by the Geological Society in the successive awards of the Murchison Geological Fund in 1885, the Murchison Medal in 1897, and the Wollaston Medal in 1909. Mr. Horace Woodward was President of the Geologists' Association 1893–4.

He married Miss Alice Jennings at Dorking, on June 5, 1873; she died in 1902. He leaves one daughter, now married (Mrs. Sydney Barnwell).

During the last five years Mr. Horace Woodward has suffered severely at times from an internal malady, but in spite of his drawbacks his Spartan courage enabled him to continue his literary labours, and he brought out the following works: E. Stanford's Geological Atlas of Great Britain and Ireland (1907, pp. x, 160, explanatory and descriptive geology with numerous maps and illustrations; a third edition, including the Channel Islands, has just appeared); The Geology of Water Supply (Arnold's Geological Series, 1910, 8vo, pp. x, 340); The Geology of Soils and Substrata (1912, pp. xvi, 366); and, jointly with Dr. Henry Woodward, a Table of British Strata (Dulau & Co.). He also contributed the geological chapters to several volumes of the Victoria County Histories. As Assistant Editor of the Geological Magazine he has for many years written very numerous reviews and notices of current geological literature up to the last.

Mr. Woodward died at his residence, 85 Coombe Road, Croydon, on Friday, February 6, 1914, and was interred at Brookwood on February 10. His memory is warmly cherished by his colleagues on the Geological Survey and by a large circle of geologists both in the Geological Society and the Geologists' Association. C. R.

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THE

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NEW SERIES. DECADE VI. VOL. I.

No. IV.—APRIL, 1914.

ORIGINAL ARTICLES.

I.—The Chiltern Wind Gaps.

By J. W. Gregory, D.Sc., F.R.S.

THE Geological History of the Thames is still the subject of conflicting hypotheses. Mr. F. W. Harmer (1907)[1] has drawn a very interesting parallel between the basin of the Middle Thames around Oxford and the Vale of Pickering in Yorkshire. The latter, as is well known from Professor Kendall's paper (1902),[2] was occupied by a glacial lake which was due to the Derwent River having had its outlet to the sea south of Scarborough closed by a dam of ice; the water rose in this lake until it overflowed at a gap near Malton; the river thus formed cut a gorge through which the drainage from the Vale of Pickering flows south-westward into the Yorkshire Ouse, and reaches the sea through the Humber. According to Mr. Harmer the Upper Thames originally discharged north-eastward through the Fens into the Wash; this outlet was blocked by the ice; the waters of the Upper Thames collected as a lake, which was discharged by overflow channels cut through the Chiltern Hills, and as the lake-level fell the discharge was maintained only through the Goring Gap at the south-western end of the Chiltern Hills. This view advances a different explanation of the Chiltern wind gaps than that advocated in a paper in 1894,[3] and is opposed to the theory of the evolution of English rivers adopted by Professor W. M. Davis in 1895.[4]

The analogy drawn by Mr. Harmer between the basins of the Upper Thames and the Vale of Pickering is very attractive; but the striking difference between the arguments for Lake Pickering and for Lake Oxford is, that for the former there is abundant positive evidence, while for Lake Oxford there is no such direct evidence. Professor Kendall has demonstrated the changes in the course of the Derwent and the former existence of Lake Pickering by convincing evidence. That the Derwent formerly reached the sea through the great valley south of Scarborough appears so obvious as to be almost indisputable. The former existence of Lake Pickering is shown by the form of the basin and the abundant deposits on its floor; and the margins of the old lake are indicated by well-developed lake beaches and deltas. If Mr. Harmer's Lake Oxford had been in existence at about the same period as Lake Pickering—and they are both assigned to the period at the close of the Boulder-clay—we might expect corresponding evidence for both lakes. On the contrary, the assumed outlet of the Thames to the Wash is very doubtful. The lake deposits on the floor of this basin are insignificant, and can be explained by local pools which would not have answered the requirements of Lake Oxford; and though the Brightwell gravels to the north of the Goring Gap are referred to by Mr. Harmer as possibly "littoral accumulations of a lake" (1907, No. 1, p. 503), there are no clear remains of lake terraces or deltas.

The strongest argument for Lake Oxford is the existence of the gorge of the Thames at Goring and of the wind gaps through the Chilterns; but re-examination of the evidence confirms my original impression that these gaps were cut by pre-Glacial rivers. They present difficulties, which appear to me insuperable, to the theory that they were cut by the overflow from a glacial lake. The second figure in my paper of 1894 (No. 3, p. 106) shows that these gaps stand at very different levels. The floor of the Hampden Gap is at about the height of 700 feet, and the escarpment beside it rises over 800 feet. The deepest of the gaps, that at Tring, has been cut down to the level of 430 feet. The Hampden Gap could only have been made by a lake which was at the level of more than 800 feet above the sea. No such lake could have existed unless the broad opening between the Berkshire Downs and the Chiltern Hills, on the floor of which the Goring Gap has been incised, was post-Glacial. The existence of Triassic drift down to the level of below 300 feet above Wallingford and near Pangbourne shows that the Thames Valley at Goring had been cut down to below 300 feet above sea-level in pre-Glacial times.[5]

The top of the gorge at Goring is at about the level of 450 feet, and even if the whole gorge below that level had been cut after the existence of the assumed Lake Oxford, the water in that lake could not have stood much above that level. The overflow from the lake might have deepened the gaps at Tring, Wendover, and Saunderton, which have been cut down respectively to 430, 503, and 461 feet; but even these three deep gaps could only have been initiated by the lake if its surface had stood over 800 feet above the sea; and that Lake Oxford could ever have stood at that level seems impossible. If these gaps had been deepened from about 540 feet, which seems to me the highest possible level of the lake, then they would have been in existence before Lake Oxford, which would explain only the deepening and not the origin of the wind gaps. The conclusion that the Chiltern gaps were cut by rivers when the Chalk extended farther to the north-west, and are a series of pre-Glacial valleys of which the rivers have been beheaded by the Thame, still seems to me the most probable explanation.

Mr. Harmer's objection to this origin of the wind gaps is based on their modern appearance and their occurrence as more or less rectilinear channels (1907, p. 503); but there seems no very marked difference between them and some of the valleys in the Wealden Downs, which would appear to be certainly pre-Glacial. It is important to remember in connexion with the form of the valleys that in all probability the Chiltern Hills were never covered with ice.

The ice which deposited the boulder-clay extended over the lowland on both sides of the north-eastern end of the Chiltern Hills, but did not cover them or reach the main part of the range. Mr. Harmer's map (1907, pl. xxxiv) shows clearly the relation of the Chiltern Hills to the boulder-clay, and the only evidence for the glaciation of the Chilterns is that based upon the plateau gravels, which, as I maintained in 1894, are non-glacial and pre-Glacial.

The view that these high-level gravels are of glacial origin has, however, been adopted by Mr. T. I. Pocock in the memoir on *The Geology of the Country around Oxford.*[6] He has clearly restated the arguments for the glacial origin of the beds; and he considers that all the Oxford district was covered by ice, and that the country has been lowered during Pleistocene times, mainly by glacial denudation, to the extent in places of 450 feet. The evidence advanced by Mr. Pocock seems inconclusive, and he quotes the late H. B. Woodward, who was superintending the survey of the district, as "strongly of opinion that none of the plateau drifts can be regarded as the immediate product of land ice, in the sense of being boulder-clay; but that there are remnants of 'washed drift' of Glacial age" (No. 6, p. 103, footnote). The distinction between glacial and non-glacial gravels afforded by the presence of Jurassic material is, of course, not available in the Upper Thames Valley; but other evidence of glacial action should be forthcoming. I go further than H. B. Woodward, by doubting whether there is any reason to regard the plateau drifts as even the wash of glacial beds. Mr. Osborne White (No. 7) and Dr. Salter (No. 8, p. 286) agree as to the fluviatile origin of these plateau drifts. Mr. White, for example, concludes (No. 7, p. 173) that "it seems almost impossible to resist the conclusion that, despite the great elevation it attains above the beds of the neighbouring streams, this gravel owes its existence to fluviatile agency, operating along the same general lines of drainage as those in existence at the present day". Mr. White adds (No. 7, p. 173), "There is no reason to think that the part played by ice in the formation of this gravel was ever more than a subordinate one."

It may be said that possibly the Chiltern wind gaps were pre-Glacial while the gorge at Goring was glacial. Mr. Harmer, however, lays stress on the probability that the wind gaps and the Goring gorge were due to the same cause, and therein I fully agree with him. Hence the theory suggested by Sir Joseph Prestwich, that the Upper Thames and Thame once discharged north-eastward into the Wash, appears improbable, and the Chiltern wind gaps may be best explained as the remains of pre-Glacial valleys, which were excavated by rivers now beheaded by the Thame.

[1] F. W. Harmer, "The Origin of certain Cañon-like Valleys": Quart. Journ. Geol. Soc., vol. lxiii, pp. 470–513, pls. xxxi–v, 1907.

[2] P. F. Kendall, "Glacier-Lakes in the Cleveland Hills": Quart. Journ. Geol. Soc., vol. lviii, pp. 471–571, pls. xx–viii, 1902.

[3] J. W. Gregory, "The Evolution of the Thames": Nat. Sci., vol. v, pp. 97–108, 1894.

[4] W. M. Davis, "The Development of certain English Rivers": Geog. Journ., vol. v, pp. 127–46, 1895.

[5] Mr. Osborne White is also of the opinion that the excavation of the Goring Gap was begun in long pre-Glacial times.

[6] T. I. Pocock, *The Geology of the Country around Oxford*, Mem. Geol. Surv. England and Wales, 1908, pp. vi, 142.

[7] H. J. Osborne White, "On the Origin of the High-level Gravel with Triassic Debris adjoining the Valley of the Upper Thames": Proc. Geol. Assoc., vol. xv, pp. 157–74, pl. vii, 1899. The view that the clay with flints on the Buckinghamshire hills is of glacial origin has been maintained by Sherlock & Noble (Quart. Journn. Geol. Soc., vol. lxviii, pp. 199–212, pls. xii–xiv, 1912). In the discussion on this paper the authors' views were generally rejected.

[8] A. E. Salter, "Pebbly and other Gravels in Southern England": Proc. Geol. Assoc., vol. xv, pp. 264–86, 1899.

II.—Notes on the Petrology of a portion of the North Kalgoorlie Field.

By R. A. Farquharson, M.A. (Oxon.), M. Sc., F.G.S.,
Petrologist to the Mines Department of Western Australia.

(PLATES VI AND VII.)

(*Concluded from the March Number, p. 114.*)

FROM the foregoing analyses there is little doubt that the rock is a hornblende-quartz-keratophyre. The term porphyrite, however, has been adopted in the mapping for convenience. It is worthy of note that a very similar rock, though greenish in colour, has been already described from Kanowna by the writer.[1] In the latter, silica amounted to more than 71 per cent, while soda reached 7·85 per cent; potash was again absent.

12237, G.M.L. 4458 E., Hyman North.[2]

The rock is finer in texture than the preceding one, but has no remains of hornblende phenocrysts, and the ground-mass is of very fine grain, and is intermixed with fine flakes of muscovite. A few of the felspar phenocrysts are cracked. There are a few aggregates of a yellow chlorite, some brown-red grains and dust of iron-ore. The 'matrix' of 12331B, G.M.L. 4458 E., Hyman North, is similar to 12237, though the former shows unmistakable evidence of shearing action, not only in the parallel orientation of sericite fibres and the presence of brownish-yellow flakes or spots of chlorite, but also in a 'lined' or 'grated' appearance in section, due beyond doubt to the sliding of one portion of the mass over another.

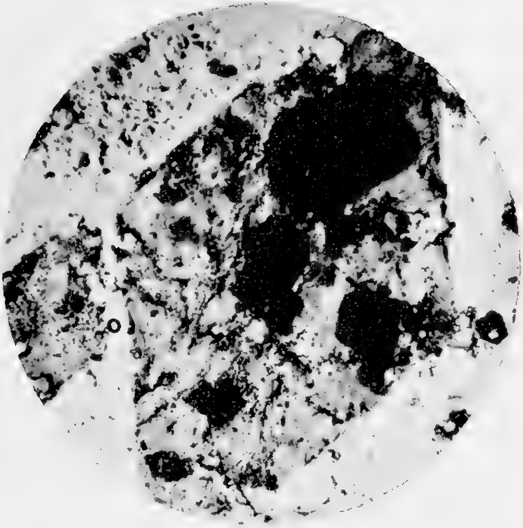
12316 (about 5½ chains north-west of south corner of G.M.L. 4161 E.) is very similar in section to the previous specimens, but the felspar both in the phenocrysts and in the ground-mass is almost all altered to sericitic aggregates, amongst which the quartz plates are easily visible.

12368, 120 ft. level G.M.L. 4406 E., Hyman, is distinctly porphyritic with ferruginous outlines of former hornblende.

[1] Bulletin No. 47 G.S.W.A., Petrological Notes, p. 71.

[2] M.C. = a weathered brownish rock. S. = minerals: felspar, quartz, chlorite, sericite, and iron-ore.

1



2

Rock-sections, Kalgoorlie.

To illustrate Mr. Farquharson's paper (see March Number, p. 113).

In No. 11106, square, columnar, and other shapes of a turbid, indistinctly twinned felspar, together with irregular patches of calcite, appear in a ground-mass that consists of small square and lath-shaped felspars, minute granules apparently of quartz, numerous round grains of pyrites, and small scales of green chlorite. The felspar, both of the phenocrysts and of the ground-mass, is more or less kaolinized, so that determination of the species is difficult. It is highly probable, however, that the rock is another variety of the porphyrite with felspar phenocrysts.

10433 closely resembles 12331A and 12368. There are large kaolinized phenocrysts of twinned albite in various forms in a ground-mass of small felspar squares and laths, without any 'flow' structure, and small interstitial plates of quartz. There are also large green chloritic aggregates without definite shape enclosing talcose fibres, and usually brown from iron oxide. These, no doubt, represent the hornblende phenocrysts noticeable in some other sections. One or two large plates of clear quartz are visible in places, and there are occasional patches of brown-stained carbonate.

12321 differs from the above only in having a larger development of granular calcite and a tendency towards felted structure in the laths of the ground-mass. A considerable amount of sericitic mica also is distributed over the slide.

In 12232 large deep-green chloritized hornblende columns and prisms make their appearance, often stained, however, by iron oxide. They are disposed in a fine-grained ground-mass which consists of more or less twinned felspar laths, and which closely resembles the ground-mass of 12376. Felspar phenocrysts are not observable in this slide.

2937 and 10434. These are blackish rocks with white, somewhat lenticular spots of a white carbonate, which, as it gives an effervescence with cold dilute H Cl, though a feeble one, is at least in part of calcite. In section green chloritic patches and granular carbonate in rounded and columnar forms, as well as in small grains, stand out of a ground-mass of minute lath-shaped and small short columnar crystals of a twinned and turbid felspar. The carbonate areas appear in places mixed with chlorite and quartz, some, mainly chlorite, have almost exactly the form of cross-sections and elongated forms of hornblende crystals (see especially 2937). It is possible, also, that some of the forms, though they show no remains of twinning, represent original felspar phenocrysts. Numerous small black grains of magnetite are scattered through the mass.

The rocks are difficult to place, but the character of the phenocrysts and the nature of the ground-mass have led to their being classed as hornblende porphyrites. A slight tendency to the drawing out of the white spots in a parallel direction is observable in the hand-specimen, a fact presupposing some shearing action on the rock-mass.

12311 is a hard reddish rock with a few dark-green specks. In section there are numerous square and columnar phenocrysts more or less decomposed with the production of kaolin and sericite. These stand out of a ground-mass consisting of a few felspar forms, granular quartz, granular patches of an iron-stained carbonate, some grains of magnetite, and a few patches of green scaly chlorite. One or two larger plates of quartz are to be observed, but phenocrysts of the mineral are conspicuously absent. The species of felspar present was indeterminable owing to the alteration the mineral has undergone.

The rock may be either a quartz-porphyry, with quartz wanting among the phenocrysts, or an altered specimen of keratophyre.

(*b*) *The Non-Porphyritic Type.*

12231. In hand-specimens, the same in appearance as the other brown specimens. In section the rock is seen to be devoid of felspar phenocrysts, and to consist of a plexus of trimmed laths of felspar, among which quartz is very hard to identify. In the ground-mass are several long, thin, acicular as well as rectangular crystals, yellow in colour, which are doubtless chloritized remains of hornblende forms. Here and there are pieces of tourmaline without definite shape, with a dichroism from deep green to pale violet or lavender.

12233 is in a hand-specimen a light-grey, compact, fine-grained rock with a brown crust. The section is composed entirely of irregularly outlined laths of felspar of considerable size, some interstitial quartz, and some aggregates and scattered scales of greenish pleochroic chlorite with grains and squares of magnetite. Phenocrysts are absent, though some of the laths attain unusual size (Pl. VII, Fig. 3). Twinning is pronounced, and measurements of extinction angles indicate albite or oligoclase-albite. The irregular nature of the outline of the laths is a noteworthy feature.

B. Rocks of Gabbroid or Doleritic Origin.

The rocks of this group are either light-grey with green spots and rather hard, e.g. 12324, or dark-green, soft, and with minute quartz crystals, e.g. 12379. As stated previously, the distinctive characters of the group are few, but generally there are clear outlines of long columnar twinned felspars, and in two specimens at least, 12324 and 12322, a kind of coarse ophitic structure.

12324. Minerals observed : hornblende, felspar, quartz, zoisite, epidote, chlorite, apatite, iron-ore.

The section consists of large ragged plates and flakes, of a pale, almost colourless hornblende that is sometimes partially chloritized, disposed amongst numerous completely turbid rectangular and columnar crystals of felspar, with idiomorphic outline. The turbidity is seen with high powers to be due to a granular mass of zoisite, epidote, and occasionally clear quartz, and is consequently to be attributed to saussuritization. Between the felspar crystals there is frequently some clear interstitial quartz that is, without doubt, original. Long needles of apatite occasionally make their appearance, and besides forms of leucoxene there are grains of ilmenite surrounded by that mineral.

The idiomorphic nature of the felspars and the platy character of the hornblende suggest a sub-ophitic structure. The rock is an amphibolized and partially saussuritized quartz dolerite.

12322 differs from 12324 only in a greater development of felspar forms, and a smaller development of the ferro-magnesian and quartz.

The felspars are also more turbid, and in them epidote is not so prevalent. Leucoxene is rare.

12370 is a rock of the soft green type.

Minerals observed: chlorite, quartz, calcite, felspar, magnetite, apatite, epidote.

Long, thin columnar crystals of felspar, partially or wholly altered to carbonate and green chlorite, with usually a green border of chloritic scales all round the crystals, are the most prominent feature of the slide. The felspar appears to be andesine. Between these forms are clear areas of quartz with chlorite inclusions; some of the quartz appears originally interstitial, but most is doubtless secondary. There are numerous apparent intergrowths of calcite or chlorite and quartz forming a micropegmatite, and though the calcite and chlorite may be due to decomposition of felspar the structure in this case is more probably of secondary origin. On the other hand, a few small areas of micropegmatite in which the felspar is only kaolinized are regarded as original. There are a few needles of apatite, numerous grains of magnetite, and some small plates of epidote.

Though the alterations to which this specimen and 12324 have been subjected are quite different, the structure of the rocks is somewhat similar. There is even in 12370 a suggestion of ophitic structure. The rock is of doubtful origin, but is classed as originally a quartz dolerite.

12377 and 12379 are of very similar type to the preceding, but though they are undoubtedly originally the same rock their structure is more indefinite. 12377, in particular, approaches 12322 in structure, and it would seem that the difference between the two is due only to a difference in the type of alteration each has undergone.

2108 is more closely grained and has a larger amount of chloritic scales. The felspar columns are very large, and the mineral is now represented largely by calcite, chlorite, and epidote, but in places by quartz and chlorite, or quartz and calcite.

In 12378 there has been a much more complete mineral and structural alteration. There are few signs of idiomorphic felspars: the structure is distinctly granular, and the slide consists of a mixture of chlorite, calcite, quartz, epidote, and iron-ore. Yellowish epidote is particularly abundant in small platy aggregates. In part of the section the constituents are arranged parallel, as if the rock had been sheared since its decomposition. One large columnar crystal with perfect longitudinal cleavage, straight extinction, very low birefringence, and a biaxial figure has been referred to zoisite.

12310 is a dark-green carbonated chloritic rock. Under the microscope, it appears at first sight to consist of a basis of almost isotropic chlorite in which are grains and crystals of a carbonate, small plates and grains of nearly colourless epidote, and some dark-grey or brown areas with the appearance of leucoxene. Closer study, however, shows that the chloritic basis contains remains of small columnar, almost lath-shaped crystals of twinned felspar. Since there appear to be no idiomorphs of any size the whole rock seems to be composed chiefly of the laths, and the suspicion arises that it is but a much chloritized form of the non-phenocrystal porphyrite. The grey or brown areas are resolvable under high powers into aggregates of minute brown-yellow rutile prisms and needles, so that these areas no doubt represent original ilmenite, or less probably biotite.

The structure of the rock is rather indefinite. It resembles that of the fine-grained ophitic dolerites, but also that of the non-phenocrystal porphyrites. The rock is difficult to place, but has been put provisionally amongst those of doleritic affinities.

12387 is a greyish-green rock with veinlets of quartz, with much carbonate, and with a somewhat sheared structure. The mineral constituents are chlorite, quartz, carbonate, and apparently some kaolinic material. In places forms are visible which by ordinary light resemble large decomposed zoned plagioclase crystals, but which by polarized light appear as mixtures of quartz and carbonate. Prisms and grains of brown-yellow rutile are scattered all over the slide, as also are small plates of clear quartz.

The rock shows no structure. It appears more allied to the diorites than to any other group.

12303. A weathered, dirty red and green rock of rather coarse texture. Minerals observed: epidote, chlorite, quartz, magnetite, apatite, and some rounded areas rendered rusty-red by ferric oxide.

There is a total absence of structure. The slide is a mineral mass in which the commonest mineral is a yellow and greenish-yellow epidote in plates and platy aggregates. With the latter are partially chloritized fibrous and strongly pleochroic collections of greenish hornblende forms, while in many places are patches of greenish chlorite. Quartz occurs in large clear cracked plates; there is much magnetite, and there are occasional apatite needles. In one place a turbid form resembling a columnar felspar is visible. The rock was with little doubt formerly an amphibolite.

Epidioritic Rocks.

Both 2950 and 11001 are specimens too much decomposed to call for description. They appear, however, to be composed of fibrous, sheafy, and divergent aggregates of a pale hornblende which has subsequently been partially altered to chlorite. They are both without normal igneous structure, and are, in consequence, set down as weathered epidiorites.

C. The Talc-Chlorite Rocks of more indefinite origin.

The rocks of this group are those composed largely of talc and chlorite, but of which the origin is doubtful. They vary in colour from red to dense black, but are commonly green. They are all soft.

3391. A blackish-green rock, with few recognizable minerals. Seen in section it consists of numerous fine fibres of a colourless mineral with low refractive index and high double refraction. Some radial extinction in sheaf-like aggregates is also to be observed. Grains of magnetite are frequent, as are patches of granular carbonate. Though in hand specimens the rock is serpentinous in character,

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Rock-sections, Kalgoorlie.

To illustrate Mr. Farquharson's paper (see April Number, pp. 150 and 155).

in section its characters more closely agree with those of a talc-chlorite rock. An analysis made in the Survey Laboratory gave the following results:—

	Per cent.		Per cent.
SiO_2	47·44	*Brought forward*	91·70
Al_2O_3	6·65	Na_2O	·33
Fe_2O_3	·76	K_2O	*nil*
FeO	6·78	H_2O + ...	5·68
MgO	26·68	H_2O −	·78
CaO	3·39	CO_2	2·06
	91·70	Total .	100·55

From the relatively high percentage of alumina and ferrous oxide, it would appear that chlorite is present in fair amount. On the other hand, as potash is absent there is no sericite. The silica percentage is in the neighbourhood of that of the various epidiorites and amphibolites, and, though not much reliance can be placed on this as a criterion, it is probably that the rock has been derived from some such original.

7006 is almost identical with 3391.

12240 is grey in colour and more or less granular, and with a soapy feel. In section it is composed of a mass of minute scales and rods of a yellowish-green mineral with rather high birefringence and noticeable pleochroism, amongst which there seem to be other very minute needles of a paler colour. Idiomorphic crystals of reddish dusty carbonate are not uncommon. There are occasional fragments of quartz, and a few small pieces apparently of felspar. An analysis of the rock made in the Survey Laboratory gave the following results:—

	Per cent.		Per cent.
SiO_2	35·90	*Brought forward*	57·90
H_2O + ...	4·71	MgO	15·69
CO_2	9·22	FeO	4·12
K_2O	2·00	Fe_2O_3	7·04
Na_2O	·26	Al_2O_3	13·48
CaO	5·81	H_2O −	1·84
	57·90	Total .	100·07

It will be seen that the silica percentage is very low; the CO_2 percentage is high, and the percentage of alumina is also comparatively high. The presence of potash with a high percentage of alumina suggests the occurrence either of felspar or of sericite. The presence of the former is demonstrably present, but the identification of the latter cannot be made with accuracy. From the analysis and the optical characters, the rock would appear to be a talc-chlorite-sericite rock with carbonate crystals, and to be derived from an amphibolite or some closely related type.

12372, G.M.L. 4320 E. "Ivy"; consists of fine scales of talc, decomposed chlorite, and granular carbonate; it closely resembles 3391.

1947 (Old Thunderbolt lease, now G.M.L. 1121 E. Devon Consols Consolidated) is another dark-green chlorite rock, which consists of lenticular areas of talc and carbonate streaked out in parallel directions, and surrounded by almost isotropic green chlorite. Crystals of carbonate are also visible, and there are occasional small plates of quartz. Brown-yellow rutile is rather common in grains and prisms.

12315 (shaft about 80 ft. S.E. of S. corner of G.M.L. 4161 E.) is a reddish rock with small plates of quartz, areas of greenish chlorite, many small brilliantly polarizing flakes that have been referred to talc, and numerous brown-red dusty aggregates and crystals. As the latter show in places distinct rhombic forms, they are, in all probability, forms of ferriferous carbonate that have been oxidized. Veinlets of quartz penetrate the rock.

12366 (dump 11 ch. N.N.W. of N. corner G.M.L. 4337 E.) is a soft greyish-green rock with a reddish tinge. There are again ferriferous carbonate crystals, and remains of small twinned, columnar, or lath-shaped crystals of felspar. The rock is of doubtful origin. It may be either a chloritized or somewhat carbonated form of the keratophyre, or it may be of amphibolite origin.

11083, "Tabby Cat" (Gibson), is a talc-chlorite rock with crystals of a carbonate. There are pleochroic halos round brown and black crystals of ilmenite in chlorite.

D. Rocks of Doubtful Origin.

1. *The Fuchsite Rocks.*

These specimens are more or less identical in appearance with those already described by the writer from other localities,[1] with the exception of 12317, which is a pale-green quartz rock with green micaceous scales in strings on the surface; they are all heavily carbonated, partly siliceous, with white quartz, and to a greater or less extent pyritic. The fuchsite occurs in films and scaly aggregates all over the rocks. Most noteworthy, however, as tending to throw some light on the mode of origin of the rocks, is the occurrence in 10439 of a development of tourmaline needles, associated with a fresh felspar and large idiomorphic crystals of a carbonate. The nature of the felspar has not been definitely established, but from measurements already made it appears to be albite. The significance of the occurrence of tourmaline has already been pointed out. The origin of the chromium oxide that has given rise to the fuchsite is still, however, to be accounted for. Attempts have already been made to explain its origin in definite terms, but one great difficulty has been that for various reasons no field evidence of its occurrence of any service can be obtained. The same difficulty has been met with in the area under consideration. The specimens were obtained from dumps of shafts to which access is no longer possible. The chromium must, however, be regarded either as original in the rock or as introduced by circulating lateral or ascending solutions to which the carbonates, the silica, and indirectly the tourmaline are due.

[1] Bulletin No. 43, G.S.W.A.: Observations on some Rocks from Ingliston, Extended Mine, Meekatharra. Also Bull. No. 47, G.S.W.A., Petrological Notes, p. 92.

It is known that the water of hot springs does contain not only CO_2 in solution but also small amounts of Cr_2O_3. Traces of chromium are contained, for instance, in the deposits of hot springs at Carlsbad.[1] On the other hand, there are in these fuchsite rocks small grains of a black or brown colour, often surrounded by the micaceous mineral, which may be chromite or picotite. At present, however, no definite views as to its origin can be put forward. It must be noted that in the cases previously described no tourmaline has been identified in association with these rocks, so that its development may be subsequent to the formation of the carbonate.

10439. A green and white, partly siliceous, carbonate rock with tourmaline, pyrite, and felspar.

The characters presented by the rock are essentially the same as those of similar rocks already described. Briefly, the section consists of a granular mass of carbonate, quartz, sericite, and fuchsite, and brown and black grains surrounded by green mica. There are small aggregates of rutile needles, some in the carbonates. Apparently a marginal peculiarity is a mixture of quartz, fairly fresh felspar, and numerous long prisms of a tourmaline with dichroism from almost colourless to brownish-green. In places the mineral is found to be apparently enclosed both in the carbonate crystals and in the felspar. (Plate VII, Fig. 4.)

11028. A dark greyish-green rock with strings of pyrites, veinlets of a whitish carbonate, and with a rather faint green tinge. In section, besides the ordinary granular mixture, there are fragmentary plates of a partially granulitized clear felspar that appears to be albite. It is in places more or less sericitized.

12257 is similar to 11028, but more heavily carbonated, and shows several veinlets of quartz with some cryptocrystalline areas of very low birefringence.

In 12256, which is a light-grey carbonate rock with greenish spots, there are much granular carbonate, small plates of quartz, and long columnar striated felspars that have been partially replaced by sericite and carbonate. There are also laths of altered felspar and a large number of opaque, squarish, and rounded granules that appear whitish or yellowish by reflected light. It was impossible to identify the felspar, but the appearance of the rock is such as to suggest the possibility of its having been the keratophyre. The small green spots in the hand-specimen are very difficult to pick up owing to their small size and the presence of sericite. It seems unlikely, however, that they are inclusions.

12317. Appears in section to be made up of quartz plates of various size rendered dusty by minute fibres of sericite and small bluish-green patches presumably of fuchsite.

2. *Rocks possibly of Plutonic Origin.*

11096. M.C. A weathered grey-green rock with numerous grains of pyrites and occasional long thin columnar and pale greenish felspars visible.

[1] Beck, *The Nature of Ore-deposits*, vol. ii, p. 426.

Minerals observed: quartz, felspar, pyrite, magnetite, granular calcite, chlorite, a micaceous mineral (muscovite).

There are long broad columnar crystals of a felspar showing either only Carlsbad twinning or none at all; other crystals, tabular as well as columnar, show broad albite lamellation and symmetrical extinction angles as high as 14°, 15°. The former are doubtless orthoclase, the latter andesine or a basic oligoclase. Quartz is abundant in a few plates that are almost idiomorphic, but mostly in shapeless areas. Intergrowths of felspar and quartz are very frequent, and of large extent, the felspar being either micacized or kaolinized. In some places tabular felspars appear like islands in a sea of clear quartz; in others the felspar of an intergrowth is optically continuous with a tabular crystal. Instances are to be seen where felspar crystals have been broken across, and in these the cracks have all become filled with clear quartz.

Granular patches of calcite and magnetite and also of chlorite, with crystal outlines, may represent an original ferro-magnesian. Flakes of a colourless micaceous mineral occur sporadically and have been referred to muscovite. Pyrites is common in the rock in grains of various size. There is no distinct porphyritic structure.

The rock is difficult to name; it resembles some hornblende granites and quartz diorites, but, though no ground-mass is noticeable, it more closely approaches in character a granite porphyry. The great amount of clear quartz and the infilling of cracks in the felspars by this mineral suggests a partial metasomatic replacement of some of the felspar by quartz.

2918 is a grey rock with dark-grey spots in a lighter rock mass, and with veins of pyrites. In section are visible large shapeless plates of clear quartz, some leucoxene areas, and much granular pyrites in a granular mass of carbonate, quartz, muscovite, and sericite. There are remains of platy felspars now sericitized, and occasionally what appear to have been intergrowths of quartz and felspar, the latter sericitized.

No noticeable rock structure now remains, so that it is impossible to come to any conclusion as to the nature of the original rock.

5. Conclusions.

Briefly, the main points which emerge from a consideration of the area dealt with in this paper are these. The earliest rocks and those that form the greater portion of the area are greenstones which comprise masses of doleritic or gabbroid type, others of amphibolite without doubt derived by extreme dynamic metamorphic action from the former, and talc-chlorite rocks which probably represent the extreme phase of chemical and dynamic alteration both of the dolerite and of the amphibolite. The movements which contributed to the production of the hornblende of the amphibolite from the augite of the dolerites or gabbros not only produced a shearing in the rocks themselves, but developed actual fissures in the rock masses, a main series at right angles to the direction of stress and no doubt a minor at right angles to the latter. Moreover, along several lines the shearing and crushing stresses were probably greater than along others, with the result that distinct lines of weakness were produced in the rocks.

At a later date, along these lines of weakness and doubtless along various fissures in the mass, there were intrusions of a highly acid dyke-rock rich in soda and with frequent hornblende phenocrysts—the albite—porphyrite or keratophyre. That this is decidedly later in origin than the greenstones is proved by its occurrence in tongues in them, and by the frequent examples in one locality of included chloritic xenoliths.

Accompanying the acid intrusions were boric vapours which not only caused the production of tourmaline both in the keratophyre and in the quartz leaders, but which, in association with other gases, without doubt exerted a pneumatolytic action on the surrounding rocks. Harker[1] has briefly described the main views now held as to this type of alteration. According to him, with the completion of crystallization in a rock magma the combined water and other volatile substances must be disengaged. The bulk of these are collected in druses and geodes or occupy fissures in the now solid rock body. Such cavities and fissures may be sufficient to permit of a general circulation through the rock mass. As cooling proceeds, however, some of the compounds crystallized at higher temperatures cease to be stable in the presence of the concentrated gaseous residuum and are decomposed with the production of new minerals. The volatile substances may or may not enter into the composition of these new minerals, but in general they do so at a greater extent at this stage than during the magmatic crystallization.

The pneumatolytic agents themselves are merely the final residuum of an igneous rock magma, and the processes are conducted at temperatures more or less elevated, though progressively declining. It is probable, therefore, that the tourmaline of the keratophyre has been produced during the later stage of the consolidation of the magma and possibly by action of the boric vapours on some of the felspar.

Further, in the lode formations kaolin and sericite are particularly abundant, and, as Flett has pointed out, this kaolinization and sericitization may be attributed in great part to pneumatolytic action. Moreover, the action of the vapours was doubtless also exerted on the surrounding greenstones, causing a propylitization which has given rise to some at least of the soft greenish chloritic rocks.

When the high acidity of the dyke is taken into consideration, and also the fact that frequent cases occur of the quartz leaders enclosing tourmaline needles, most of the leaders and of the auriferous quartz of the lodes may be regarded as genetically connected with the dyke. as being the later more acid or wholly acid phase in which the rarer mineralizers—in this case boric vapours—were particularly abundant. It is probable also that auriferous veins will be found not only at the junction of the dyke with the greenstones, but in some cases for some distance into the greenstones themselves.

[1] Harker, *Natural History of Igneous Rocks.*

III.—An Inquiry into the Origin of "*Batrachioides the Antiquor*" of the Lockport Dolomite of New York.[1]

By E. M. Kindle.

(PLATES VIII AND IX.)

THE physical history of sedimentary rocks is written in characters which sometimes baffle the skill of geologists to interpret. This may be because geologists are prone to devote too little time to the study of rocks in the making, and too much to the finished products of sedimentation. It is well to remember that the most unpromising pool or bit of lake shore may hold the key to the most perplexing of these hieroglyphics.

A brief review of the history of the various attempts to explain certain curious impressions found on the Niagara dolomites of Western New York will illustrate the need of closer observation and study of some of the phenomena of our ponds and lakes resulting from the interaction of wind and water.

The highest beds of the Lockport Dolomite which are exposed in the Niagara Falls region have been cut through by the Erie Canal near Pendleton, N.Y. The rock here is a thin-bedded, black or steel-grey dolomite with numerous thin films of black shale separating successive laminæ in some of the beds. Some of these beds show gently concave plates of limestone which have the surface completely covered by shallow contiguous pits (Pl. VIII, Fig. 1). These curious impressions are usually about 1 inch in width and have a depth of from $\frac{1}{4}$ to $\frac{1}{2}$ in. They are remarkably uniform in character, as shown in the Figure. Well-developed ripple-marks with an amplitude of $1\frac{1}{2}$ inches appear on the surface of closely associated beds.[2]

Professor James Hall,[3] who appears to have been the first to observe these impressions, ascribed them to the action of inorganic agencies akin to those which produce concretionary structures.

In 1850 Professor Benjamin Silliman brought these curious structures to the notice of the American Association for the Advancement of Science[4] and attributed their origin to the agency of great numbers of gregarious fishes. He stated that excavations of similar character and appearance are now made by tadpoles in shallow pools. The eminent naturalist Alexander Agassiz[5] was inclined, however, to doubt the ability of tadpoles to produce the regular shallow pits on mud which Silliman and Hitchcock ascribed to them. A few years later Professor Edward Hitchcock referred to the Lockport Limestone impressions in connexion with the discussion of very similar markings on the Triassic sandstones at South Hadley, Massachusetts. Professor Hitchcock's remarks bearing upon the kinship in origin of tadpole nests and the impressions on the Lockport Limestone are as follows: "I had been led to doubt the tadpole origin of the South Hadley and New York specimens, by the fact that in many cases the cavities were arranged in lines, and sometimes too it was clear that

[1] Published with the permission of the Director of the Geological Survey of Canada.

[2] Folio U.S. Geol. Surv. No. 150, pl. xxv.

[3] Geol. New York, 1843, pt. iv, pp. 92–3, fig. 29.

[4] Proc. Amer. Assoc. Adv. Sci., vol. iv, pp. 10–12, 1850.

[5] Ibid., p. 12.

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Photographs of (1) *Batrachioides antiquor* and (2) 'Tadpole nests.'

they occupied ripple marks. But I found the same thing at Tadpole City. Deep as the hole is, and slight as could be any aqueous current there, I found that ripple marks, of about the same width and depth as those on the rocks, had been formed over a part of the bottom, and of course the tadpoles chose the furrows rather than the ridges for making their holes. Another circumstance showed how their holes came to be arranged in lines more or less, even where there were no ripple marks. As the water became shallow, I found that the tadpoles would collect in great numbers just along the surface of the water, at its edge, and there of course would the work of excavation be most thorough. But as the water was constantly sinking, successive rows would thus be produced. In fact, until the rains destroyed this city, I could not see but that all the phenomena on the rocks were reproduced. And I know that these cavities were formed by tadpoles, because I saw the animals at work in making them. And had the spot been so situated that a gentle influx of water as by a tide, or a freshet, should bring in mud to fill the cavities before they were erased by the rains, they might have been preserved indefinitely; and perchance sometime be converted to rock, such as the South Hadley shale, or the Niagara sandstone." [1]

Professor Hitchcock evidently considered the 'Niagara Sandstone' (Lockport Dolomite) impressions to have originated in a manner analogous to those of the Connecticut Sandstone which he named *Batrachoides nidificans*.[1] He suggested tentatively that these impressions represented 'mud nests' of Silurian batrachians and proposed the name *Batrachoides* the *antiquor* in the following passage: "And what is still more important, the facts would prove the same thing in respect to a period so early as the time of the Niagara Group of New York, which belongs to the lower part of the Upper Silurian; an epoch far earlier than any other in which traces of batrachians have been discovered. Therefore I have called the New York impressions *Batrachoides* the *antiquor*."

The writer recently published[2] a photograph of a specimen of Hitchcock's *B. antiquor*, but postponed any discussion of the nature of the impressions till the present occasion.

Regarding Professor Silliman's suggestion that the impressions represent the work of small fishes, it may be observed that very few fishes are known in the Silurian anywhere, and that the only fish-remains which have been discovered in the Silurian formations of this region were obtained from beds 100 feet or more below the beds under discussion. With respect to the batrachian origin of the impressions, it may be noticed that thus far no direct evidence has appeared that any representatives of the Amphibia were in existence as early as Silurian time. Comparison of the accompanying photograph of the Lockport impressions, with Hitchcock's figure of the Connecticut sandstone impressions called *B. nidificans*, strongly suggests that the two have had a similar origin. There is no doubt either in the mind of the writer that the dimpled surfaces on the Lockport Beds are the product of the same agencies which now produce 'tadpole nests'.

[1] *Ichnology of New England*, 1858, pp. 121–2.
[2] Folio U.S. Geol. Surv. No. 150, pl. xxv.

In accepting the conclusion of Hitchcock, that the Lockport and Connecticut sandstone impressions originated in a manner analogous to 'tadpole nests', it will be necessary to reconsider the question of origin of the 'nests'. As already noted, so eminent a naturalist as Alexander Agassiz doubted the ability of tadpoles to produce the impressions ascribed to them. There can, however, be no doubt that tadpoles are sometimes found associated in shallow water with the 'nests' which have been attributed to them, but the association of the two will not, taken alone, establish a causal relationship between them. The two photographs (Pl. VIII, Fig. 2, and Pl. IX, Fig. 3[1]) show the appearance of the structures called 'tadpole nests' by Hitchcock and others. The photograph (Fig. 2) shows a shallow pool which occupied the bottom of a small abandoned quarry. The writer spent several hours about the sides of this pool collecting fossils. It thus happened that abundant opportunity was afforded while cracking open blocks of the adjacent limestone to observe closely the behaviour of the tadpoles associated with these pits. When these observations were made the size of the pond had been reduced by evaporation till it was generally less than 1 foot in depth, and the hundreds of tadpoles in the water were evidently suffering from over-population and reduced food supply. A number of the tadpoles which had died, presumably as a result of this condition, were furnishing food to the survivors. In feeding upon their deceased associates, five or six tadpoles usually attached their mouths to the body of the dead batrachian, and in this way a ring of half a dozen vibrating tails almost constantly surrounded the bodies of each of the victims. During the feeding the movements of the concentrically disposed tadpoles tended to disturb the sediment immediately below. At the time the observations were made the writer believed that the shallow pits had been produced entirely by these activities of the tadpoles. But more recent studies of interference ripples has led him to conclude that the 'nests' are interference ripple-marks slightly modified by the tadpoles. The point may be raised that the photograph of interference ripples here reproduced (Pl. IX, Fig. 4) shows the pits separated by sharp angular ridges, whereas the 'nests' have comparatively flat or gently rounded partitions. The writer has found that different examples of interference ripples show a rather wide range of characteristics with respect to this feature. Just as ordinary ripple-marks show crests, which in examples produced under different conditions range from sharply angular to nearly flat or rounded, so interference ripples exhibit corresponding variations of type. Successive observations of one set of interference ripples continued for three days by the writer have also shown that ageing of the impressions under the influence of a shifting direction of the wind tends to alter angular partitions to rounded ones. The comparative rarity of the so-called 'tadpole nests' affords strong evidence that they are the product of the wind rather than of tadpoles. The writer has observed many scores of ponds with tadpoles,

[1] The writer is able to publish this photograph through the courtesy of Mr. G. K. Gilbert.

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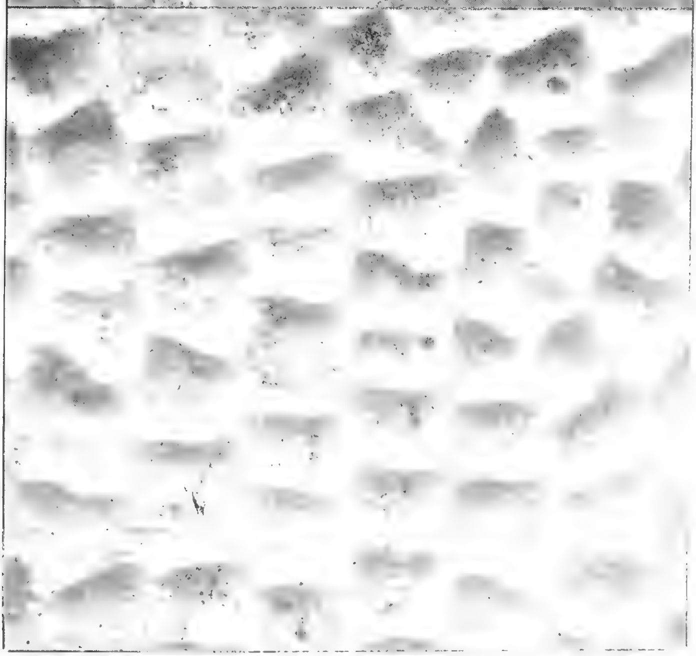

4

Photographs of (3) 'Tadpole nests' and (4) interference ripple-marks.

but has only once seen the dimpled surface called 'tadpole nests' by Hitchcock associated with them. Inquiries have been made of a number of zoologists for information concerning the alleged tadpole habit of making nests, but the writer has been able to find no zoologist who was aware that tadpoles ever indulged in such a habit. If such structures were ever produced by tadpoles one might reasonably expect to find them generally associated with these creatures. These considerations, together with the fact that the oscillation of the water under certain conditions of wind action produces structures similar to the so-called 'tadpole nests', lead to the conclusion that those observed by Hitchcock and others are interference ripple-marks, perhaps slightly modified in outline by tadpoles.

Comparison of the photograph of the impressions on the Niagara Dolomite with the photograph of interference ripples which was made from moulds of interference ripples taken under water at Britannia beach, Ottawa, indicates clearly a similar origin for both. The strong resemblance of the two photographs is such that one can scarcely doubt that they have had an analogous origin. Interference ripples are much less common than the wave-like type of ripple so frequently seen in shallow waters. They are developed under shallow water[1] in which the ordinary wave generated by the action of the wind on the surface is split up into two or more sets of oscillations moving in different directions. The gradual movement of fine sediments by such conflicting currents, which may proceed so slowly as to be nearly imperceptible to the casual observer, results in the coarse cell-like structure shown in Pl. IX, Fig. 4. The small eddies and cross currents which originate about the ends of bars, piers, or stranded logs are favourable localities for the development of interference ripples. The cast of the interference ripples shown in Fig. 4 was made in water about 6 inches deep, which was protected from any but the lightest wave action by stranded logs on all sides. If the writer's interpretation of the Lockport limestone impressions is correct, they too were formed in shallow waters in which bars probably furnished the special conditions required for the development of interference ripples.

EXPLANATION OF PLATES VIII AND IX.

Plate VIII.

Fig. 1. Dimpled surface on upper beds of Lockport dolomite at Pendleton, N.Y., "*Batrachioides* the *Antiquor*" of Hitchcock.
,, 2. 'Tadpole nests' on bottom of shallow pond, Hamilton County, Ind.

Plate IX.

,, 3. Photograph of 'tadpole nests' in small pond. By W. W. Gilbert.
,, 4. Interference ripple-marks. Photograph from mould of cast taken under water at L. Deschenes.

[1] The writer's observations have been limited to shallow water, but it is probable that interference ripple-marks would be produced in water of considerable depth where a rocky ledge or other obstruction to normal oscillation of the water generated by wave action extended into a sandy bottom.

IV.—Studies in Edrioasteroidea. IV. The Edrioasters of the Trenton Limestone.

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

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(PLATES XIII–XIV.)[1]

(*Concluded from p. 125.*)

THE Cover-plates of the radial grooves are preserved here and there in specimen A, notably over the oral centre (Pl. X, Figs. 1, 2, 5, 7, 8), but in B they are preserved over the whole of the grooves and the mouth, though pressed down on to the floor of the grooves and into the peristome (Pl. XI, Fig. 1). Cover-plates are also present in the British Museum specimens, and are almost complete in E 16054.

Each cover-plate corresponds in position with a floor-plate; so that, like the floor-plates, the cover-plates form a double series of alternating plates meeting in a zigzag median suture. The almost straight or slightly rounded outer margin of each cover-plate fits into a bevelled facet just within the rounded edge of the radial groove where the floor-plate begins its downward slope (Pl. X, Figs. 5, 7). This feature is well shown in specimen B, and there the floor-plate also shows, on each side of the facet, and distinct from the peripodium, a slight depression, possibly for the insertion of a muscle or ligament, or possibly for the reception of the accessory cover-plate shortly to be described.

From their facets the cover-plates stretch across the radial groove, either in a straight line (Pl. X, Fig. 5) or slightly arched upwards. Often, however, as in B, they have been pressed down into the groove, whether by contraction of tissues after death, or, as is more probable, by the pressure of the superincumbent rock.

The cover-plates abut closely, in tessellate fashion, when closed in the normal position over the radial groove. When pressed inwards, however, as in B, they have sometimes been made to imbricate with adoral overlap. This suggests a possibility of the converse action, namely, that in life they may have assumed a similar imbricate arrangement when they opened outwards, thus forming a slight gap between adjacent plates.

A gap may also have been produced by the opening of the accessory cover-plates. These are minute triangular plates frequently to be observed, one at the outer end of each suture between adjacent cover-plates, and therefore lying just over the pore (Pl. X, Fig. 8). Minute depressions in the floor-plates have already been mentioned as possibly the facets for their reception. These accessory plates are not always to be distinguished, but this may in some cases be due to the state of preservation, and the difficulty of detecting the sutures bounding such minute structures. When clearly seen, it is obvious that they were definite elements demanding explanation, and not caused by accidental cracks.

On the other hand, there is in E 16054 an occasional appearance of separate small plates along the median suture. In this case the appearance is probably due to fracture. The specimen has been

[1] Plates X–XII appeared in the March Number, pp. 115–25.

crushed, but the arched cover-plates, instead of being pushed into the groove, have resisted the pressure and given way at the summit of the arch.

Here we may turn to the differences presented by the subvective skeleton of *E. levis*. The floor-plates are not separated from the interradial plates by a continuous line of curved sutures, but join them by irregular angular sutures, varying in accordance with the outline of the plates against which they abut. And, just as they merge in this way into the interradials, so are they not distinguished from them by so sudden a rise above the general level as is the case in *E. bigsbyi*. Thus the rays of *E. levis* are less conspicuous, and, by reason of this as well as of their more regular curvature, have not that curious appearance of independent life.

The relations of the floor-plates to the cover-plates are also slightly different. A single cover-plate, instead of abutting on a single floor-plate, abuts as a rule on two. Consequently each floor-plate, instead of a single curved facet for its cover-plate (with a possible minute facet at each side thereof for an accessory plate), has one long curved facet for the cover-plate hinged to it, and a very short straight facet where the adjacent cover-plate plays against it. The longer curved facet, where distinctly observed, is on the distal side of the floor-plate. There are no accessory plates.

On the floor of the groove, the perradial zigzag channel is less marked, and the side-branches from it less pronounced. The surface of the plates between these branches is gently rounded, almost flat, and not ridged. The outer pore-depression and the inner, more adradial, depression are well marked, but not very distinct from one another. The specimens do not yield convincing evidence for or against the passage of pores to the interior.

The appearance of additional cover-plates along the median line is very strongly marked in certain regions of E 15900 (Text-fig. 2). These regions are just where the ray curves more sharply and passes along the periphery, and is therefore most subjected to both natural torsion of the cover-plates and post-mortem pressure. The former force seems to have induced an adcentral bending of the cover-plates as they approach the median line, and this is best seen towards the proximal end of the disturbed region (Fig. 2, II). Nearer the periphery the latter force has compressed the grooves so that the cover-plates have been raised, as in E 16054, and pushed together. Consequently their adcentrally directed ends have been broken across, and in some places seem to form a double row of small plates, alternating with each other and with the main cover-plates from which they are derived (distal end of Fig. 2, II). Occasionally each of these small plates is again divided by an apparent suture transverse to the median line of the groove, so that two small plates go to each main cover-plate (Fig. 2, III). The regularity of these appearances is diminished in proportion as the specimen is cleaned and carefully examined. None the less, the divisions between the plates look like true sutures, and they may represent a structure that arose naturally during life rather than the consequence of some accident or of post-mortem pressure.

Tegminals.—In both species, where the grooves meet at the peristome the cover-plates continue round them, and so form a roof over the actinal centre. No special plates are developed here, but all are serially homologous with the other cover-plates and have, in *E. bigsbyi*, the same accessory plates. There are, however, two differences: (1) in order to cover the space, these plates are rather larger and less regular in shape than normal cover-plates; (2) they appear suturally united to form a solid tegmen, and in consequence are rarely pressed into the mouth-cavity as in B, but are frequently preserved in place even when the other cover-plates have disappeared (Pl. X, Fig. 1).

The Peristome, which lies beneath this tegmen, consists of a roughly circular opening, surrounded by a frame. Owing to the persistence of the tegminal plates, the peristomial structures are rarely well shown, but it has proved possible to develop them on the right side of specimen A (Text-fig. 3). Here the floor-plates of one side of the right posterior ray curve round the right posterior interradius and meet those of the adjacent side of the right anterior

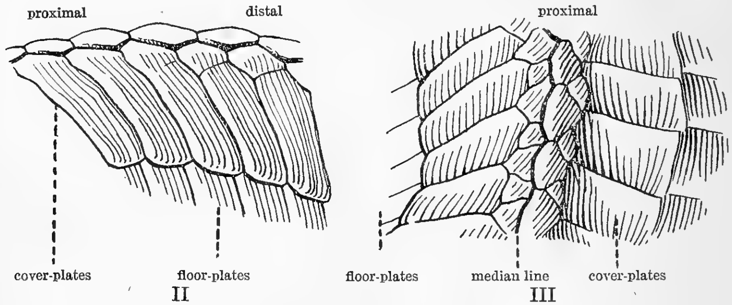


FIG. 2. Cover-plates of *Edrioaster levis*, from the adoral face near the periphery of the holotype. × 6 diam.

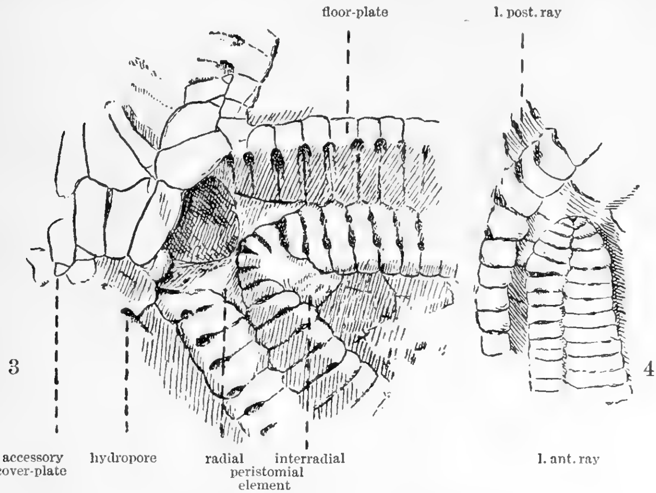
II. From the left anterior ray, showing the curvature of the admedian tract and its gradual change into a distinct plate.

III. From the anterior ray, showing small plates similar to those in II, but with yet smaller plates between them.

ray, so that there is a fan-like arrangement of the pore-bearing sutures about the interradius. Four of these plates, two from each ray, appear to be fused at their marginal ends; and the solid plate thus formed stretches centrifugally along the interradius, serving as a fixed abutment for the adjoining floor-plates to the number of $2\frac{1}{2}$ on each side. In other specimens five floor-plates may compose this interradial plate. Rarely, as in E 16172, there are two such compound plates formed in an interradius. These plates were noticed by E. Billings (1854, p. 273), who doubted whether their pores penetrated to the interior, but observed and figured a pore in the posterior angle as larger than the others.

As the floor-plates curve round to meet those of the next radius, they become separated from the corresponding floor-plates on the opposite side of their own radius. Between the two rows on the floor of the groove, there seems to be intercalated another skeletal element, over which the groove itself passes centripetally down into the thecal cavity. As seen from above each of these radial flooring elements has a roughly triangular outline, and meets its fellows to left and right by its basal angles, thus forming a continuous ring round the central space. In 1854 (p. 271) E. Billings figured these plates as seen from the interior (fig. 11) and in section (fig. 12). He described them as triangular, and partly covered by the plates at the interradial angles, and as having "an elevated border on the side next the mouth, below, caused by the bending down of the plate."

To obtain a clearer idea of the relations of these apparent radial mouth-plates, I have removed the adapical structures and the matrix from the under side of rays III and IV in the peristomial region of E 16172. After three months of this labour it has been possible to produce Fig. 2 of Plate XIV, but the structures are still rather



EDRIOASTER BIGSBYI. Specimen A.

FIG. 3. Portion of the peristomial region more developed by preparation than in Plate X, fig. 1. × 4 diam.
,, 4. The distal end of the left anterior ray, showing floor-plates only. × 4 diam.

difficult of interpretation. The peristome, as viewed from the inside of the test, is surrounded by a stout frame forming an elevated border. This border is flattened rather curiously, and is widest on the perradii, so that while its inner or adcentral margin is approximately circular, its outer or adperipheral margin approaches a pentagon with radial angles. The interradial tracts of this mouth-frame are, it is clear, composed of those floor-plates which, as already described, are fused to form the adoral or proximal interradial plates. The pores between these plates penetrate to the interior all the way round, though they decrease in size as they near the interradius. The radial tracts of the frame likewise seem to be composed of the floor-plates, which are here enlarged at their perradiad ends. There do not seem to be any distinct interradial elements, but the appearance of such in external view, as described above, is almost certainly due to the overlapping of the perradiad ends of the proximal floor-plates. The difficulties of interpretation are due to the very close union of the plates to form a rigid mouth-frame, and to the cracks that develop during the process of preparation.

There appears to be in each ray some slight projection of the interporal region of a pair of floor-plates, each forming a process directed away from the perradius, and placed at the spring of the elevated border. These are not so regular that one can infer their normal and constant presence in every ray of all individuals, but they may well have some significance as processes for the attachment of muscles or other internal organs.

There are no traces of any other hard mouth-parts or of any skeletal connexion between the mouth-frame and the lobes of the adapical integument.

These peristomial structures are the stereom counterpart of the various channels and cavities observed in the internal cast of *Edrioaster buchianus*, and confirm the interpretation of those cavities offered in Study II, pp. 197, 198. Their relations to the soft parts will be discussed later.

The Interradial Areas are irregular in shape according to the varying curves of the radial grooves. In A, the posterior area, from the concavity of the left posterior ray to that of the right posterior, is 19·5 mm. across; but a part of this is occupied by the recurved end of the right posterior groove. Of the other areas, the widest is the left anterior, which measures 13 mm. at its widest part; and the narrowest is the right posterior, which measures about 7·5 mm. near the periphery (Pl. X, Fig. 1). In B the same general relations obtain (Pl. XI, Fig. 1). In E 15930 the chief difference seems to be that the left anterior area is relatively wider. In *E. levis*, on the other hand, the relations, owing to the solar curvature of all the rays, are quite different; thus, in E 15900 the measurements are: posterior, *circa* 24 mm.; left and right anterior, both 12 mm.; right posterior, *circa* 16 mm. (Plate XII).

The Interradial plates are irregular polygons, apparently with no definite arrangement. A single plate of moderate size abuts on the compound interradial element of the peristomial frame and is usually bordered by about four floor-plates on each side. This is followed by a number of plates different in each interradius. Thus in A the numbers are: l. post., 2; l. ant., 3; r. ant., 4 or 5?; r. post., 4. In B these plates almost agree in numbers and arrangement with those of A. In these two individuals the curvature of the rays is almost exactly the same, and there is also a remarkable general similarity in the number, shapes, and arrangement of the interradial plates. This similarity may imply either that the plates are heritable morphological elements, or that similar mechanical causes acting upon an indifferent plate-forming tissue have produced a similar breaking-up of the stereom. That the latter is the true interpretation seems to be proved by the other specimens, for in them the same plates cannot be identified.

The interradial plates are stout, those not far from the periphery in E 15930 having a thickness of 1 mm. and over. They are tessellate, with vertical sutures, but, as already described, dipping with oblique sutures under the radial floor-plates. There are no pores through or between the plates. The surface in well-preserved tracts is coarsely pustulate (Pl. XI, Fig. 1). The pustules are distinct, and spring from an irregularly reticular surface. E 16054, being a small and presumably a young individual, shows the pustules rather faintly and of smaller size than in the other specimens; a large proximal plate in the left anterior interradius has the pustules distributed about 9 to 1·5 sq. mm. In E 15930, an individual of more than twice the diameter, the pustules on a similarly placed plate run about 9 to 3 sq. mm.

These pustules are not due to the breaking up of growth-lines by radial stresses, but they may very well have been tubercles bearing minute spines. Such spines, being very loosely attached, would readily fall off after death, and would in any case escape observation owing to their minute size. I have searched for them in the very small amount of available material, but in vain, unless a tiny rod (·8 mm. × ·25 mm.) in the left anterior interradius of E 15930 may possibly be one.

The specimens of *E. levis* differ in having no distinguishable pustules, a feature to which my attention was first directed by Mr. Walter Billings. The exposed surface of these two specimens has been somewhat worn (one had apparently been trodden on), and this has exaggerated the smoothness. When other parts were freed from their protecting matrix they presented a surface that might be described as slightly vermiculate, or perhaps more accurately as ‘scrobiculate’.

The Anus is well shown in specimen A (Pl. X, Fig. 1). It lies between the distal end of the right posterior groove and the bend in the left posterior groove, and is surrounded by a number of small plates, which must have lent greater flexibility to the test in this region. Twelve of these plates meet round the actual opening, from which the sutures between them radiate (Pl. X, Fig. 9). They are not of equal length or width, and meet the smaller surrounding plates quite irregularly. There is no imbrication. The area covered by small plates rises up in a slight dome above the general level of the interradius, but at its summit is again pushed in just round the anal opening, possibly in consequence of post-mortem contraction. The anal dome is not sharply defined on its right side, but seems continuous with a general swelling of the thecal surface in that direction. The rectum may have lain under here, and this, if so, would indicate that the gut had a dextral coil. The similar appearances in *E. buchianus* have received a similar interpretation from Professor Jaekel and myself (cf. Study II, p. 199).

In specimen B (Pl. XI, Fig. 1) the periproctal plates are disturbed, but the dome is discernible, as also the swelling on its right. In the two specimens of *E. levis* the periproctals are numerous and small, but do not appear to be elongate to any considerable extent.

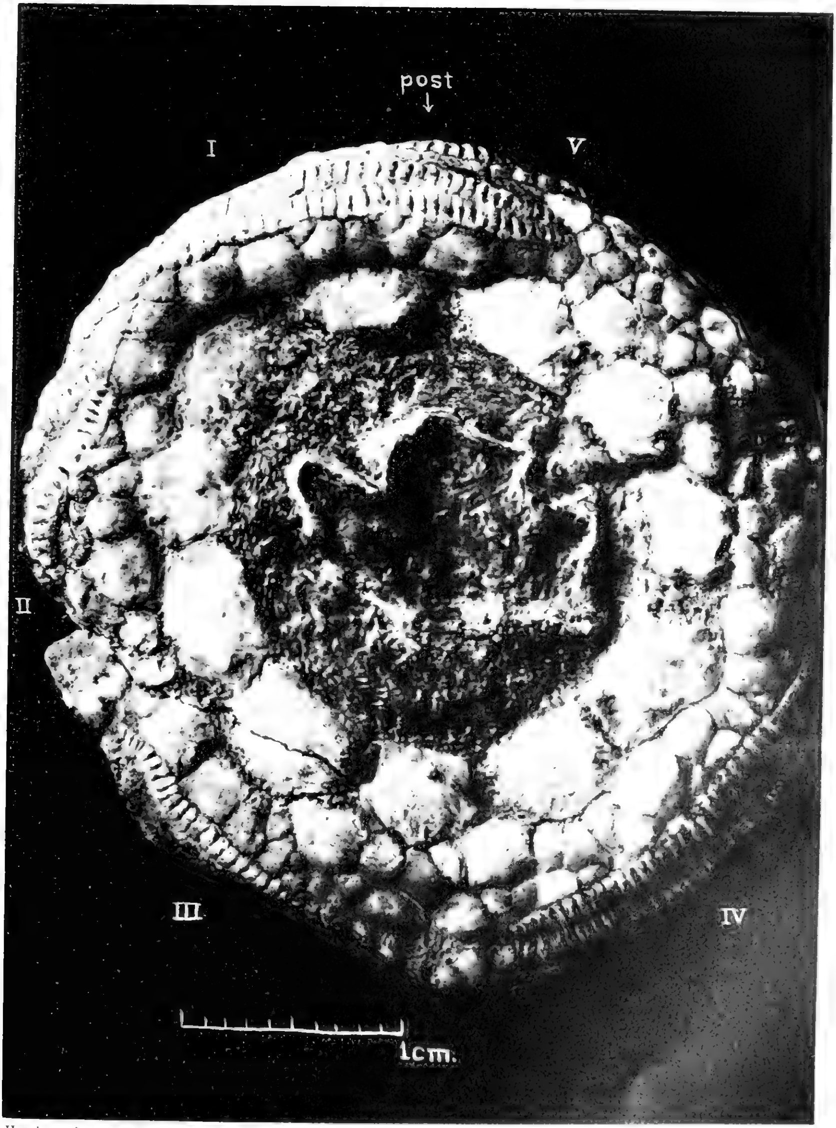
The Hydropore, or at least the thecal opening which I thus identify, lies at the adoral end of the posterior interradius, close to the margin of the right posterior groove. It is clearly seen in specimen A (Pl. X, Figs. 1 & 7) and B (Pl. XI, Figs. 1 & 2), and indeed can always be recognized whenever that portion of the test is plainly exposed. Its normal appearance is that of a small, slightly curved slit, approximately parallel to the right posterior ray. Its length is 1·1 mm. in A, 1·5 mm. in B. It widens slightly towards its adoral end, deepening at the same time, and becoming darkened with matrix, an appearance that indicates an oblique passage of the canal through the test. Specimen B shows the margin of the slit raised in a rounded rim, well defined at the adoral end and along the right side, but broken up into lobes on the other side. The slit is contained in two plates, and crosses the suture between them at right angles. The actual canal is only in the adoral of these two plates, and it may be that this plate is homologous with the interradial elements formed by the fusion of the peristomial floor-plates; but all the plates in this region are so closely united that the sutures are hard to trace. The tract of the adoral plate between the rim of the hydropore and the rounded margin of the peristomial floor-plates bears, in specimen B, about fifteen minute, closely-set pustules. Spinelets, if attached to these, would have provided a filter for the inflowing water.

Specimen E 15930 seems to show a slight branching of the slit, such as occurs during ontogeny in the very earliest stages of the folding that forms the madreporite of a recent Echinoid or Asteroid. Such branching increases the ciliated area by which the water-current is driven. The hydropore was not mentioned by E. Billings at any time, but his restored figure (1854, Fig. 10) shows that he observed something in the region where we now know it to occur.

The Under or Adapical face has been exposed by patient preparation in specimen A (Pl. X, Fig. 3), but is better shown in specimen C (Plate XIII). It is bounded by the distal halves of the four sinistrally curved radial grooves, which, as seen from below, of course appear dextral or solar. Their ends are quite definite, as described above (Text-fig. 4); when Plate X was drawn, some twelve years ago, they were still obscured by matrix, which has since been removed. The concave space included by these may, as in *E. buchianus*, be divided into three regions: the Peripheral Area, the Frame, and the Central Area.

The Peripheral Area is formed by a ring of plates serially homologous with the interradials of the upper face, and, in specimen A, connected with them by a single row of small plates passing between the rays. These peripheral plates of the under face are a little smaller than the majority of the interradials, and form, in specimens A and C, a single row, occasionally doubled, bordering the rays. In E 16173 (*E. levis*) these plates are relatively smaller than in A and C, and occupy a relatively wider belt, so that on both counts they are more numerous; they differ further in being more distinctly of two sizes, namely, larger plates with smaller ones surrounding or intercalated between them.

The Frame is a ring of larger and thicker plates (see the section, Pl. X, Fig. 9), the number of which appears to have been twelve in C,



Herring photo.

EDRIOASTER BIGSBYI.

and probably the same number, not more, in A. In *E. buchianus* eleven such plates were counted, but the general shape and arrangement are the same in the two species. The inner margin of each frame-plate in *E. bigsbyi* is straight or concave, not convex as in *E. buchianus*. I have not observed on them any sign of tubercles or pustules, such as appear to have existed in *E. buchianus*.

The Central Area, in all specimens where any portion of it can be seen, is darker in colour and irregularly wrinkled (Pl. X, Fig. 11). It was doubtless covered by a flexible integument, filled with minute plates, which it has been possible to observe, though not clearly to photograph, in some tracts of specimen C (Plate XIII) and in E 16172 and E 15930. This scaly skin was attached to the frame-plates, and may as a rule have spread over them to some extent, especially at the sutures between them. The minute plates were tangentially elongate, and when closely pressed together, as in the folds, tend to project and to imbricate.

The adapical face of E 15930 (Pl. XIV, Fig. 1) differs from that of all other specimens observed in the apparent absence of a frame: the plated integument seems to stretch right up to the peripherals. In the region that should be occupied by the frame there are, however, appearances as though the integument had been thrown into raised circular or crescentic folds, each bounding a strongly pustulate floor. It may be that this floor is formed by the fusion of small plates, or that it indicates a frame-plate underlying the plated integument.

In cleaning away the matrix, it was peculiarly interesting to discover in these species the lobed central evagination, which I first made known in *E. buchianus*. Its pentagonal shape is not so obvious here. In A it is roughly triangular, with a short base in the left anterior interradius, and two long sides directed to a distinctly folded apex in the right posterior radius. One of these sides may be regarded as containing the lobes of the right anterior and right posterior interradii, and the other those of the posterior and left posterior interradii. In C (Plate XIII) the irregular lobate edge of the posterior half of this evagination is clearly seen, and we are perhaps justified in distinguishing the lobes of the three posterior interradii.

Prolonged preparation and repeated examination of the area surrounded by the lobes in A, C, and E 16172, have convinced me that there was no central opening of a permanent nature, such as E. Billings mentioned as apparently present (1854, p. 272). Neither is there evidence for pores of any kind in any part of the adapical face. It is perhaps hardly necessary to add that there is no sign of any stem or root, unless the central lobed region be regarded as in some sense the homologue of a stem.

Discussion of the physiological and morphological meaning of the structures herein described is reserved until, in a forthcoming Study, the structure of *Steganoblastus* shall have been redescribed. At this point, however, the distinctive features of the genus *Edrioaster* and of its four known species may be resumed in the following diagnoses.

Family EDRIOASTERIDÆ.

Edrioasteroidea with a theca composed of separate and relatively thin plates, and apparently without permanent attachment; with a subvective skeleton partly visible in apical aspect, and composed of floor-plates and movable cover-plates, having pores between the floor-plates; interradials of oral face continuous with those of apical face; central area of apical face covered with more flexible integument, bearing smaller plates; a hydropore (probably always) pierces an adoral interradial of the posterior interradius.

The genera are *Edrioaster* E. Billings, 1858; *Aesiocystis* Miller and Gurley, 1894; *Dinocystis* Bather, 1898; *Lebetodiscus* Bather, 1908.

Aesiocystis comprises a single species, *A. priscus*, based on four imperfect specimens from the Trenton Group of Mercer Co., Ky. (Bull. Illinois State Mus. Nat. Hist., No. 5, p. 13, pl. ii). The genus was placed by its authors in the family Hemicystidæ, but their description and figures show that it was almost certainly an Edrioasterid; indeed, my chief doubt is whether the species was not actually an *Edrioaster*.

Edrioaster.

An Edrioasterid with pores of subvective groove within the tract protected by cover-plates; with interradials all tessellate and separated from the central apical region by a frame of stouter plates; on the apical face the peripheral plates are variable in size but not minute, the central plates are minute and tend to imbricate.

Edrioaster bigsbyi E. Billings.

An *Edrioaster* with height of theca about one-third of diameter, periphery roughly circular; with rays clearly raised above general surface, and floor-plates clearly demarcated from interradials; rays I, II, III, IV have a contrasolar curve, ray V a solar curve, ray IV bends upwards within r. ant. interradius; interradials of oral face bear coarse, sparse pustules.

This is the genotype.

Edrioaster buchianus E. Forbes sp.

An *Edrioaster* with height of theca one-half the diameter or more, periphery sub-pentagonal with convex interradii; with rays apparently not raised above general surface, but with floor-plates clearly demarcated from interradials; rays all have a solar curve; interradials slightly pustulate?

Edrioaster saratogensis Ruedemann.

An *Edrioaster* with depressed theca (height probably about one-fourth diameter), periphery sub-circular to sub-pentagonal with convex interradii; with rays clearly raised above general surface, and floor-plates not regularly demarcated from interradials; rays all have a solar curve; interradials relatively few, and all, as well as cover-plates, densely and finely granulose.

This diagnosis is based partly on the description and figures of Dr. Ruedemann (1912, Bull. N.Y. State Mus., No. 162, p. 86, pl. iii), partly on squeezes which he was so kind as to send me. Dr. Ruedemann, apparently being acquainted with none of my previously published

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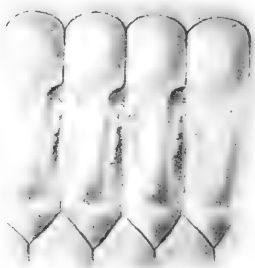

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London Stereoscopic Co.

EDRIOASTER BIGSBYI.

work on *Edrioaster,* naturally found difficulty in describing his imperfectly preserved specimens. The subvective skeleton has the normal *Edrioaster* structure, and the so-called 'subambulacral plates' marked '*a*' in pl. iii, fig. 4, are incorrectly drawn. The absence of evidence for a contrasolar ray has already been alluded to (p. 122). The 'triangular oral plates' are presumably the interradial elements of the mouth-frame. The cover-plates slope from their outer margins towards the oral pole; those pushed into the groove tend to imbricate adorally.

The original specimens came from sandstone in the Snake Hill shales of Saratoga Co., N.Y. These beds are supposed to lie just above the Basal Trenton, and below the *Prasopora* zone. The species is therefore the oldest of the four here discussed.

EDRIOASTER LEVIS n.sp.

An *Edrioaster* with height of theca about one-third of diameter, periphery roughly circular; with rays scarcely raised above general surface, and floor-plates not clearly demarcated from interradials; rays all have a solar curve; interradials faintly scrobiculate, not pustulate.

Holotype, Brit. Mus. E 15900.

EXPLANATION OF PLATES.

PLATE XIII.

Edrioaster bigsbyi. The adapical face of specimen C, of the Canadian Geological Survey, showing the peripheral portions of rays I–V, the eleven large frame-plates, and the lobed evagination of the central integument, the small plates of which are not clearly seen. × 3 diam.

PLATE XIV.

Edrioaster bigsbyi.

Fig. 1. The adapical face of E 15930, with same orientation as Plate XIII. The minute plates of the central integument are well shown. In the place of the frame are the circular elevations of this integument described on p. 169. Photographed by Mr. H. G. Herring. × 3 diam.

Fig. 2. Part of the circumoral region of the test of E 16172, seen from the interior, as described on p. 165. Drawn by Mr. W. G. Browning. × 3 diam.

Fig. 3. Some floor-plates of E 16172, showing the ridges that lead from the peripodia to the perradial channel. Drawn by Mr. G. C. Chubb. × 10 diam.

V.—SOME NOTES ON A DEEP BORING THROUGH THE CHALK OF DENMARK.

By H. FABER, F.C.S., and W. K. SPENCER, M.A., F.G.S.

EARLY in the year 1913 the Copenhagen Museum of Mineralogy and Geology issued a report[1] upon a most interesting deep boring in the Chalk at Gröndal, just outside Copenhagen. The results are so striking in respect to the thickness of chalk passed through that it appears desirable to bring them before the notice of English geologists. The estimates of the thickness of the English Chalk

[1] *Dybdeboring ved Köbenhavn, 1894–1907,* ved E. P. Bonnesen, O. B. Böggild, og J. P. J. Ravn, Copenhagen, 1913.

which are considered to be the most reliable are those given by Rowe from measurements of the various zones in the Isle of Wight and Dorset. These are approximately as follows:—

		Isle of Wight. feet.
Zone of	*Belemnitella mucronata*	475
,,	*Actinocamax quadratus*	343
,,	*Marsupites*	47
,,	*Uintacrinus*	34
,,	*Micraster cor-anguinum*	310
,,	*M. cor-testudinarium*	52
,,	*Holaster planus*	60
,,	*Terebratula gracilis*	65
,,	*Rhynchonella Cuvieri*	84
		1,470

Further north a much greater thickness of the two upper zones is suspected. Thus Rowe estimates that at least 400 feet of 'quadratus' chalk occur in Yorkshire. This cannot be the full thickness, for, although *Actinocamax granulatus* is abundant, specimens of *A. quadratus*, the Belemnite characteristic of the upper part of the zone, have only been met with in the very highest beds. We also know that 'mucronata' chalk of a higher horizon than that found in either the Isle of Wight or Dorset is found in Norfolk, and that higher horizons are represented on the Continent. Nevertheless, nobody could have expected that results at all comparable with those given in the report would be obtained.

The boring was taken through 2,742 feet, and yet the bottom of the Chalk was not reached. Indeed, Ravn, from the fossil evidence, regards the boring as only reaching the level of the zone of *A. quadratus*. His table reads as follows:—

		feet.
Alluvial and diluvial		34
The Danian Chalk		86
Upper 'Mucronata' Chalk	about	1,580
Middle and Lower 'Mucronata' Chalk	about	400
'Quadratus' Chalk	at least	642

If this table is correct it is obvious that the 'mucronata' chalk may be of a greater thickness than the whole of the remaining Chalk, and should therefore be capable of much more minute subdivision than has hitherto been attempted.

The following paragraphs give some general account of the methods adopted and the lithological and palæontological evidence as to the succession of the strata. It will be seen that the investigators have good evidence to offer in support of their conclusions.

History of the Boring.

The boring was initiated as an attempt on the part of the Frederiksberg District Council to obtain water. A depth of 230 feet was reached, and then the search for water was abandoned. The engineer, Marius Knudsen, offered, however, to proceed with the boring in the interest of science at a very reduced cost, and the late Professor Ussing was successful in obtaining a grant from the

Carlsberg Fund in order that the work might be undertaken. The Frederiksberg District Council promised to pay for the coal used. The idea was to bore completely through the chalk to the underlying strata, which, it was estimated, would be reached at a depth of 1,600 feet.

The American method of boring was employed. A heavy broad chisel was used, fixed on a heavy iron rod suspended by means of two steel links from a stout manilla rope. The apparatus was worked up and down by machinery in such a way that the engineer could tell how the chisel worked and could keep it turning round. When enough material had been cut loose it was brought up by letting down a 'sand pump' or syringe and filling this several times with the chalk suspended in water. Of course, the material became very much pounded up. Large pieces were sometimes obtained either by first boring a small hole and then chipping the chalk into the cavity thus obtained or, when the chisel failed to turn and therefore made a narrow cut, by cutting open with a ring-shaped chisel.

The boring was 24 inches in diameter for the first 90 feet. It was then reduced to 15 inches. When, in May, 1896, a depth of 1,222 feet was reached, 12 in. tubing of soft steel in 8 ft. lengths was let down nearly the whole depth (for 1,211 feet), and the boring was continued with a 12 in. chisel. In September, 1901, a depth of 1,577 feet was reached. From this point a 9 in. chisel was used. In 1902 the borehole between 1,577 ft. and 1,630 feet was widened to 12 inches, and by this means larger pieces of rock with fairly good fossils were obtained. An attempt to continue the steel tubing downwards was not successful. A depth of 2,742 feet (860·6 metres) was reached in March, 1907. The boring was still in chalk, and beyond this depth the American method of boring was impracticable. The borehole, however, is kept open for a possible later extension by 'diamond boring'.

The boring took a longer time than had been expected, as either flint or very stiff clayish marl caused great difficulties. Grant after grant was generously voted by the Carlsberg Fund. The State also contributed. The total amount expended was about £8,100.

It was found that the temperature increased 1° C. for each 46·1 metres, and that the increase of temperature was quite uniform. Observations were made for each 50 metres.

The Rocks and Fossils of the Strata through which the Boring passed.

The value of the evidence as to the thickness of the strata passed through depends largely upon proof that the strata were horizontal. If the beds were at all steeply inclined entirely fallacious results might, of course, be obtained. We shall see that both the lithological and palæontological evidence offers strong proof that the beds were almost, if not quite, horizontal. It may be mentioned, in passing, that the continuation of the Danian and '*mucronata*' beds across the Sound into Sweden is in itself good *prima facie* evidence that there are no steep folds in the Chalk in this immediate neighbourhood.

The rocks show a regular succession in their lithological features. The 'Saltholmskalk' is met with for 86 feet. Below that 880 feet of soft chalk occur. In this there are many layers of flint. Down to 400 feet the flints are mostly black, from 400 feet to 900 feet they are a white opal. The flint layers gradually disappear. The soft chalk is succeeded by chalk with alternating soft and hard layers (1,000–1,600 feet). From 1,600 to 1,700 feet there is a hard limestone graduating to marl. From 1,700 to 2,742 feet the rock is a marlstone with layers of light and dark marl, which increase in frequency, darkness, and proportionate content of sand as the boring deepens.

The mineral analysis of the material suggests from the proportion of sand to that of calcium carbonate that there was on the whole a deepening of the water in which the rocks were laid down, but the depression was not quite continuous. There appears to have been a slight elevation during the period represented by the rocks met with from about 1,850 to 2,250 feet, followed again by a lowering of the floor of the sea.

That this regular succession is accompanied by horizontal bedding is shown by the larger pieces of chalk obtained from the depths 1,600–1,630 feet. At these depths the chalk contained thin layers of clay, and the chisel-marks were always at right angles to the layers. Similar evidence of horizontal layers was obtained from lower depths.

The palæontological evidence suggests that the following strata are met with:—

0–4 feet	Alluvium.
4–34 feet	Diluvium.
34–120 feet Saltholmskalk	Danian.
120–923 feet Skrivekridt with Flint 923–1,700 feet (about) Chalk without Flint	Upper 'Mucronata' Chalk.
1,700–2,742 feet Grey Marl with Sand	Middle and Lower 'Mucronata' Chalk. 'Quadratus' Chalk.

One of the first objections which may occur to the reader is that there is no certainty of origin of any of the fossils. The chisel in being lowered might chip off a fossil at any depth from the sides of the boring, and this would fall to the bottom and be listed as found at a much lower horizon than that to which it really belonged. The lining of the first 1,200 feet with steel tubes prevented, at any rate, fossils from these depths (and the point is vital to the evidence) from being mixed with the lower fauna.

The great thickness of the 'upper mucronata' is of course very surprising. No one would have imagined that the 'mucronata' chalk could have exceeded 500 feet in thickness, and it is necessary therefore to examine very carefully the evidence upon which the above table is based.

The Skrivekridt with flints contained the following 'mucronata' fossils: *Terebratulina gracilis*, v. Schloth., sp. (270 feet); *Cidaris baltica* (Schlüt.) (780 feet). Fragments which appeared to be *Lima denticulata*, Nilss., sp., and *Scaphites constrictus*, Sow., sp., were found at depths of 330 and 511 feet respectively.

The chalk without flints (923–1,700 feet) contained *Scalpellum cretæ*, Stp. (1,274 feet), and *Serpula conica*, v. Hag. (1,280–1,360 feet).

Fragments which appeared to be those of *Sc. constrictus* were found at the depth of 1,580–1,590 feet. About this same depth, where it will be remembered large lumps of chalk were obtained, there occurred *Scalpellum cretæ*, *Membranipora crassa*, Marss., and a *Terebratulina* cf. *ornata*, Roem., all of which suggest a Skrivekridt fauna. The marlstone (1,700–2,742 feet) yielded *Metopaster tumidus*, Spencer, var. *radiatus*, Spencer (1,920 feet), and *Metopaster undulatus*, Spencer (2,015–2,070 feet). Both these Asteroids indicate a horizon not lower than the 'middle mucronata'. *Pollicipes fallax*, Darw. (2,070 feet), and *Crania antiqua*, Defr. (2,380 feet), suggest according to the authors a 'mucronata' or 'quadratus' horizon for the chalk near the bottom of the boring. The occurrence of *Belemnitella lanceolata*, v. Schloth., sp., at a depth of 2,648 feet seems to indicate, together with the preceding evidence, that the boring had now definitely entered 'quadratus' chalk.

Besides this positive evidence it appears to the authors of these notes that the fact that no plates of *Marsupites* and *Uintacrinus* were found is good proof that these horizons were not reached.

Ravn, in a general summary of the results obtained, states that Moberg and Hennig in studying the Chalk of Scania find that the sea broke over South Sweden in the Lower Senonian. The sea increased in depth through the 'quadratus' and into the 'mucronata' period. It then receded for a time (about the 'middle mucronata') and afterwards increased in depth more quickly than before.

These observations support the evidence from the boring in Denmark. The analyses of the material from the boring (on samples from each 50 feet) show that the marly chalk from the lowest point is fairly rich in sandy particles, and that these particles, which imply the proximity to the coast, decrease in quantity higher up. This is followed by a definite increase in the proportion of sand at a depth of about 2,250 feet, until at 2,100 feet there is a definite layer of sand. The proportion of sand a second time decreases until we reach a pure white chalk. This seems to prove that the lowest strata reached by the boring were formed in a somewhat shallow sea, which gradually increased in depth, again became more shallow, and finally deepened rapidly.

Ravn thinks that if the boring could be continued further the bore-hole would soon find the shallow-water Lower Senonian deposits which form the base of the Chalk in Denmark.

Conclusions.

The authors of the report are to be highly congratulated on the careful manner in which they conducted their investigations, and on the convincing detail which they carefully set out. All the fossils were submitted to palæontologists familiar with the group which they investigated. Elaborate chemical analyses were undertaken by Professor Billmann, and these are of great help to the argument. Records of the increase of temperature as the boring proceeded downward were also made.

The results obtained add interest to investigations upon the English 'mucronata', and especially the 'mucronata' of Norfolk. Although the Trimingham Chalk has been shown to be of higher horizon than that found in any other English locality, no one has yet been able to determine its exact relationship to other English Chalk in situ. A boring at Mundesley or at some other point on the eastern coast appears to be necessary if it is desired to make our knowledge of the English Chalk complete. It is to be earnestly hoped that some such boring will be undertaken at no very distant date.

REVIEWS.

I.—Cambridge County Geographies.

Merionethshire. By A. Morris, F. R. Hist. Soc. Small 8vo; pp. 166, with a Physical and a Geological Map, and 48 illustrations in the text; cloth boards. Cambridge University Press, 1913. 1*s*. 6*d*. each.

MERIONETHSHIRE is a maritime county of North Wales, open to Cardigan Bay on its western side, and enclosed north, east, and south by the counties of Carnarvon, Denbigh, Montgomery, and Cardigan respectively. It is more mountainous than any other part of North Wales, except perhaps Carnarvonshire. Its deep and secluded valleys, with the ruggedness and variety of its elevated districts, give it a particular charm and interest. The varied panoramic views from its heights surpass anything to be seen in Wales.

The nature of the rocks enables a portion of the country to be devoted to slate-quarrying. It is the only county in Wales in which gold has been found (at Dolgelly) in quantities sufficient to pay for working. (See Geol. Mag. 1865, p. 558.)

No isolated, solitary peak of the Welsh mountains shows such a wreck of stone as Cader Idris. With an elevation of 2,927 feet above the sea-level, it marks the starting-point from which a long chain of primitive mountains extends in a north-east direction to the Berwyns and on to the borders of Shropshire. (p. 13.)

The Harlech Dome, as it is called by geologists, is a large, irregularly-oval track, lying between Dolgelly and Harlech, and ranging northward to Maentwrog. It is occupied by unfossiliferous grits, and purple and green slates. It holds a very important place in the physical features of North Wales, being the site of the great Merionethshire anticlinal, in which the rocks dip in opposite directions like the roof of a house. On the flanks of these sloping rocks the fossiliferous flags and grits of the Lower Cambrian Series are observed to rest. (p. 35.)

The Lingula Flags are divided into three groups—the Maentwrog, the Festiniog, and the Dolgelly Groups. The first is characterized by its jointed dark-blue ferruginous slates, the second by hard micaceous flags, and the third by soft, black slate, which shows a black streak when scratched. (p. 35.)

The range between the Rivers Eden and the Mawddach in the neighbourhood of Dolmelynllyn has always been famous for its fossils.

The Ordovician occupies the largest area in North Wales. It spreads in numerous undulations around the towns of Bala and Corwen; it forms the main construction of the Arenigs, the Aran, the Gader group, and the Berwyns; and in it we have the Festiniog, Corris, Abergynolwyn, and Aberllefenni slate quarries.

The Silurian Series stretches from near Bala to the eastern borders of the county. The term 'Bala Beds' is given to these rocks all over Wales, because they are best developed from Dinas Mawddwy by Bala to Bettws-y-Coed. (p. 36.)

The largest 'fault' in the British Isles cuts through the middle of Bala Lake from south-west to north-east. Professor Sir Andrew Ramsay has made the Bala Lake historic by his description of its glacial origin; indeed, the whole region is classic ground to the geologist.

In addition to its scenery (unsurpassed by any other county in Wales) Merionethshire is full of interesting relics and antiquities. It is rich in churches, abbeys, castles, manor houses, Roman remains, whilst its survivals of Welsh manners, habits, and customs exceed all the other counties of Wales and would alone suffice to attract the intelligent visitor.

Mr. Morris's handy County Geography, from its small size and completeness, will be found well suited for a pocket companion.

II.—Text-book of Petrology, Volume I.

The Petrology of the Igneous Rocks. By F. H. Hatch, Ph.D. 7th edition, revised. Cr. 8vo; pp. xxiv + 454, with 154 figures. London: George Allen & Co., Ltd., 1914. Price 7*s.* 6*d.* net.

LAST year Dr. Hatch and Mr. R. H. Rastall published the *Petrology of the Sedimentary Rocks*, styling it "Text-book of Petrology, Volume II". It was then understood that a volume uniform with this and dealing with igneous rocks would appear shortly: this volume is now before us in the form of a revised edition of Dr. Hatch's "Text-book of Petrology", first published in 1891, but almost entirely rewritten in 1909. The two volumes form a textbook which claims to constitute a brief but complete summary of the whole science of rocks.

In revising the book the author has had occasion to write two new chapters on Pyroclastic Rocks and on the metamorphic derivatives of igneous rocks, the latter really forming a supplement to the more general treatment of metamorphism found in the *Petrology of the Sedimentary Rocks.* Here the metamorphosed igneous rocks are classed as: plutonic gneisses, schists derived from hypabyssal, from volcanic, and from pyroclastic rocks; such a classification can only be applied when the origin of the metamorphic rocks can be ascertained. For the subdivisions of the plutonic gneisses the five groups suggested by Dr. Teall in 1907 are used. These groups are based primarily on mineralogical constituents and to a subordinate extent on structure, and, in the present state of our knowledge, they form most useful divisions. By using the mode of origin as a basis of classification in this chapter Dr. Hatch has compelled himself to omit some interesting types of metamorphic rocks which were not dealt with under the sedimentary rocks. Thus we look in vain for any account of the granulites, though the more basic pyroxene-granulites appear under plutonic gneisses.

As regards the rest of the book, it is practically a reprint, with a few additions and corrections, of the fifth edition (1909) of the "Text-book of Petrology". The fact that this book has run through so many editions is sufficient proof of its excellence, and it is so well known that it is quite unnecessary to call attention to its merits. The additions are very few: the subject of dynamic metamorphism is treated rather more fully, and a table of mean refractive indices of minerals has been added. Birefringence is still stated as 'weak', 'moderate', or 'strong', though it has been pointed out that to give the actual values of the greatest and least refractive indices would be the more satisfactory procedure, and would make this part of the book far more useful.

The classification of igneous rocks which was introduced in 1909 has been retained and, in the case of the gabbros, a further subdivision into a labradorite and an anorthite series has been suggested. Objection has been raised to Dr. Hatch's classification on the ground that it is neither consistently mineralogical nor consistently chemical. However, no classification is free from such objections, and Dr. Hatch's scheme is one which has been found to have many advantages.

In revising the descriptive part of the book the author has not everywhere succeeded in including the results of most recent work—in fact, there are very few references to any work published since 1910. Thus borolanite is still classed with the alkali-gabbros, though in a recent paper Dr. Shand has pointed out its affinities with the syenites and has described new rock-types associated with it. 'Spilosite' on p. 29 is obviously a misprint for 'spilite', but this is the only mention made of this rather important group of rocks, and no reference is made to the important paper by Dewey & Flett, published in this journal in 1911.

The printing is done very well, and the book is vastly improved by the reproductions of a large number of excellent photographs by the Geological Survey and by Dr. H. H. Thomas.

III.—Hints on Collecting Geological Information and Specimens. By G. W. Grabham and Stanley C. Dunn. pp. 24. Khartoum: published by the Sudan Government. Price 6*d.*

THIS little book is the work of the two geologists who constitute the personnel of the Geological Survey of the Anglo-Egyptian Sudan. When the task of surveying an area of nearly a million square miles is allotted to so small a staff of professional geologists progress must necessarily be slow, and it has been thought desirable to enlist the services of other Government officials to furnish the Survey with geological information concerning the districts its members are not able to visit. These directions have accordingly been issued to afford some guidance as to the information to be furnished and the specimens to be collected. The latter subject might perhaps have been more fully treated, for a good collection representing the rocks, minerals, and fossils of an area is more likely to be of real value than attempts at geological description by those who have an imperfect knowledge of geological principles and little or no experience in field work. Owing to the circumstances of the country special attention is given to water supply, and the authors insist on the importance of recording the geological and hydrographical data afforded by wells. The book concludes with tables describing the characters of the commoner minerals and rocks.

The "Hints" are written in simple language, and should be of value, not only for their immediate purpose, but also in spreading an interest in geology amongst those who have such magnificent opportunities of doing good scientific work if they will only make themselves sufficiently acquainted with the subject.

IV.—Brief Notices.

1. New Zealand. Mines Department (Geological Survey Branch).

Seventh Annual Report, June, 1913. pp. 115–42, with 3 maps.—This contains a general summary of the progress of the Survey and six special reports, dealing with economic geology, by P. G. Morgan and J. Allan Thomson. A report by J. A. Bartrum, on the geology of the Te Puke District, Hauraki District, Auckland, contains notes on the economic and general geology and on the petrography of the area. Some interesting hypersthene-bearing rhyolites and andesites are described.

List of the Minerals of New Zealand. By P. G. Morgan and J. A. Bartrum. pp. 32. 1913.—As it is intended to publish a handbook to the minerals of New Zealand, this list is to be regarded as provisional; it has been compiled at very short notice to accompany the "Catalogue and Description of Exhibits of the Mines Department" prepared for the Auckland Exhibition. Even in this incomplete state this publication will be of much value. It contains an alphabetical list of minerals and of materials of economic importance, with the localities at which each occurs and abundant references to the literature.

2. Miocene Ostracoda.—Dr. Bela Zalanyi has issued in the Mitt. Jahrb. k. Ungarisch. geol. Reichsanstalt, vol. xxi, pt. iv, pp. 87–152, pls. v–ix, a most valuable paper on the Miocene Ostracoda of Hungary. Forty-one species are described, of which twenty-five are new to Hungary and twelve are new to science. Dr. Zalanyi has given large and excellent figures, and has paid especial attention to the hinge and muscle-spots of these small Crustacea, and the paper should be of much interest and service to students of European forms.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *February* 4, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Lithology and Composition of Durham Magnesian Limestones." By Charles Taylor Trechmann, B.Sc., F.G.S.

The present communication is the result of a somewhat close inquiry into the composition and lithology of the Magnesian Limestones of Durham in all their divisions and conditions of alteration.

More than ninety analyses were carried out, of which seventy-eight are herewith presented. Several of the rocks were sliced and stained with Lemberg's solution.

Care was exercised, before a sample was taken, to ascertain the degree of alteration, through segregation or otherwise, which the rock had suffered.

The results show that the formation maintains, generally speaking, a highly dolomitic character, with certain important exceptions. Those portions which show a calcareous composition may be regarded as the result of one of three main causes:—

(1) Original conditions of sedimentation, during which dolomitic deposition or processes of secondary dolomitization were temporarily arrested. Calcareous beds with a Brachiopod fauna are extensively developed near the base of the Lower Limestone in the south-western portion of the area.

(2) Escape from secondary dolomitization. Portions of the Shell Limestone reef, notably at Tunstall Hill, from causes only partly explicable, have escaped conversion into dolomite.

(3) Calcareous segregation, penecontemporaneous with or subsequent to deposition.

The paper is intended to be purely a record of observed facts, and no theoretical questions are raised; but internal evidence on several points is brought forward in favour of the view of direct sedimentation of dolomite from the waters of the Permian sea. The view that the bedded dolomites are the result of secondary dolomitization of calcareous organisms is a very improbable one. The question of the secondary dolomitization of the Shell Limestone reef is discussed.

The dedolomitization of the formation is due to the mechanical washing-away of powdery dolomitic material through the interstices of the rock. The nature of this material was investigated chemically and microscopically. It results from the withdrawal of interstitial calcite, both through former processes of segregation and under existing conditions through the action of percolating water.

No evidence of any leaching-out of magnesium carbonate from the rock was found. Dolomite, even in a fine state of division, is almost insoluble relatively to calcite, but a question certainly arises as to whether such was also the case in earlier periods, in presence of saturated or supersaturated solutions of sulphates.

The nature and distribution of the true cellular rock are discussed, and modes of origin are suggested.

Some general deductions are drawn from evidence of insoluble residues.

Finally, a summary of the general conditions of deposition of the Durham Permian, from the Marl Slate upwards to the Salt Measures, is given, so far as seems legitimately deducible from the available facts.

2. "On the Occurrence of a Giant Dragon-fly in the Radstock Coal-measures." By Herbert Bolton, M.Sc., F.R.S.E., F.G.S., Reader in Palæontology in the University of Bristol.

The writer describes the structure of a wing-fragment found some years ago upon the Tyning waste-heap at Radstock Colliery (Somerset), by Dr. E. A. Newell Arber, F.G.S.

The fragment consists of the proximal third of a left fore-wing. It is remarkable for its size, being 64 mm. long and 40 mm. broad, the complete wing having an estimated length of 190 mm., or 7·5 inches; the whole insect (with wings extended) must have had a span of over 400 mm., or 16 inches.

The anterior wing-margin is strongly tuberculated proximally, and more distally bears a closely-set series of pointed spines directed outwards towards the wing-apex. The hinder wing-margin is also spinous, the spines being a little way inwards from the edge, and possibly serving to interlock the fore and hind wings during flight. The radial and median veins are missing, but the characters of the costa and subcosta on the anterior portion of the wing, and of the cubital and anal veins on the hinder part, show clearly the close relationship of the insect to the members of the family Meganeuridæ, a group including the enormous *Meganeura monyi*, Brongniart, from the Stephanian of Commentry (Allier). The wing is referred to the genus *Meganeura* as a new species. The precise horizon from which the shale was derived cannot be determined, as the Tyning waste-heap has received material from five different collieries.

Annual General Meeting.

2. *February* 20, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The Reports of the Council and of the Library Committee were read. It was stated that of the 65 Fellows elected in 1913 (2 more than in 1912), 48 paid their admission fees before the end of that year, making, with 16 previously elected Fellows, a total accession of 64 in the course of 1913. During the same period the losses by death, resignation, and removal amounted to 43 (9 less than in 1912), the actual increase in the number of Fellows being, therefore, 21 (as compared with an increase of 5 in 1912). The total number of Fellows on December 31, 1913, was 1,308.

The Balance-sheet for that year showed receipts to the amount of £3,367 8*s*. 11*d*. (excluding the balance of £641 2*s*. 3*d*. brought forward from 1912), and an expenditure of £3,137 12*s*. 1*d*.

The Reports having been received, the President presented the Wollaston Medal to Dr. John Edward Marr, F.R.S., addressing him as follows:—

Dr. Marr,—I am pleased that it has fallen to my lot to address, on such an occasion as this, one with whom I have so long enjoyed an intimate friendship, and by whose work I have profited so greatly.

At the conclusion of a distinguished University career you commenced, in 1878, a series of investigations, through which your name will always be associated with the Lower Palæozoic rocks. Concentrating your attention first on the zoning of the strata between the Coniston Limestone and the Coniston Grits in the Lake District, you continued the work of Hughes, Aveline, and Salter, established a classification, and discussed the division between the Silurian and those Cambrian subdivisions of Sedgwick which are now known as Ordovician. In 1880 you carried your researches into North Wales, and instituted a comparison of the sequence as there developed with that of the Lake District. During the same year you laid before this Society the results of your visit to Bohemia, where you had been commissioned by the University of Cambridge to investigate the 'Cambrian' and Silurian sequences, with special reference to the boundary between them. In carrying this work to a successful issue, you were not only able to institute a comparison of the Bohemian and British developments, but incidentally to show that there existed serious objections to the acceptance of Barrande's 'colonies', both on palæontological and on stratigraphical grounds. Extending your investigations to Scandinavia, you proved that Sedgwick's classification was applicable in that country also, and that the principal stratigraphical and physical break occurred at the base of the equivalents of our May Hill Beds.

Your ripe experience of the Lower Palæozoic rocks was then turned to account in South Wales, where, in collaboration with the late T. Roberts, you undertook the task of subdividing the groups which had been outlined by the early surveyors. Your success in carrying out this programme may be judged when I say that during the recent re-examination of the district by the Geological Survey all the subdivisions made by you and your colleague in 1885 were adopted, and will be utilized in the forthcoming maps and memoirs.

Returning later to the scene of your earliest labours, with the late H. A. Nicholson as your colleague, you completed further palæontological zoning in the Stockdale Shales, and proved by precise field-work that an appearance of unconformity between the lowest zone and the Ashgill Shales was defective and due to strike-faulting.

In 1891, with Dr. A. Harker, you made a detailed study of the effects produced by the intrusion of the Shap Granite upon the surrounding rocks. Your familiarity with the Lake District strata, combined with the petrographical skill of your colleague, enabled you jointly to produce a classic account of the phenomena of contact-metamorphism, as exhibited in calcareous and siliceous sediments and in igneous rocks.

Of late years physiographical problems have engaged your attention, and as a result of your observations on mountain-lakes it may be expected that a wiser caution will be exercised than heretofore in identifying rock-basins as such and in postulating glacial erosion for tarns.

But it is not only this long record of original research, of necessity incompletely outlined, which the Council have had in mind in making this award. They remember that since 1880 you have been continuously engaged at your old University in assisting the Woodwardian Professor to create the foremost school of geology in Britain. The influence of your teaching in the lecture-room, in the field, and as conveyed by your textbooks has extended farther than perhaps you yourself realize. A happy combination of the power to make original research with a facility for imparting your knowledge has enabled you to exercise a profound influence on the growth of our science.

It is, therefore, with great satisfaction that I hand to you, on behalf of the Council, the highest honour which it is in their power to bestow—the Wollaston Medal.

Dr. Marr, in reply, said :—

Mr. President,—I feel that the award of this Medal is due to a combination of a number of favourable circumstances.

I have been fortunate in having worked and published papers in conjunction with many geologists, including T. Roberts, Nicholson, Harker, Garwood, and Fearnsides. Two of them have, alas! passed away, and one of the great griefs of my life was the loss of that ardent geologist and genial companion, Alleyne Nicholson.

My long association with this Society as Officer and Member of Council has brought me into contact for many years with men from whom I could learn the results of the recent discoveries in our science.

I regard this award as made not only to myself but to the Cambridge School of Geology, and in speaking of this school would first bear tribute to the advantage of the teaching which I received in my undergraduate days from Professor Hughes and Professor Bonney. During the seventies a number of brilliant geologists emerged from that school, of whom you, Sir, were one. I cannot help acknowledging also the benefits of the teaching in the field which I received from an Oxford man whom I have the honour of counting as a friend of over forty years' standing—Mr. Tiddeman.

I have, as you observed, for many years been myself a teacher in the Cambridge School, and here again have benefited from the ardour and enthusiasm of my pupils. Their cordial congratulations to me on receiving this award show that they, as well as I, appreciate the honour.

Before passing from the subject of Cambridge I must refer, Sir, to our old College. It is no doubt a satisfaction to you as to me to find the names of five members of St. John's enrolled in the lists of the Wollaston Medallists within the last twenty-five years.

I thank the Council most sincerely for the bestowal of this their highest award. There is, however, an honour which I should rank still higher, and that is the cordial approval which I feel that the Council and general body of Fellows would accord to one who did his utmost to serve the interests of the science and of the Geological Society to the end of his life. The desire to gain this approval will surely stimulate me to work in the future.

The President then presented the Murchison Medal to Mr. William Augustus Edmond Ussher, F.G.S., addressing him in the following words:—

Mr. Ussher,—For more than forty years, as a member of the staff of the Geological Survey, you devoted yourself whole-heartedly to the work entrusted to you. Though at one time or another you were engaged in various parts of England, the South-Western Counties are those with which your name is most closely associated. Indeed, among the many distinguished men who have laboured in Cornwall, Devon, and Somerset, you have done more than most to unravel the tangle of Palæozoic rocks and to classify the Newer Red rocks there exposed.

So long ago as 1875 you communicated your first paper on the Trias to this Society, and two years later you followed this up by a comparison of the Triassic development of the South-West of England with those of the Midlands and of Normandy.

At this time also you began to publish the results of those researches on the Palæozoic sequence which were destined to fill so large a part of your official career. Partly in association with the late A. Champernowne, and with help derived from the writings of De la Beche and other early workers in the same field, you proceeded with what seemed the almost hopeless task of interpreting the structure of the country and defining the limits of the Carboniferous rocks and of the Upper, Middle, and Lower Devonian groups. It is not possible for me, on this occasion, to trace the steps by which you reached your final conclusions. I can only refer to your published accounts in the Journal of this Society, in the Memoirs of the Geological Survey, and in the Transactions of the Devonshire Association, and assure you that the exceptional difficulty of the task which fell to you, involving as it did a bewildering complexity of structure, difficult palæontology, and for a time at least an inadequate topographical basis for your work, is recognized by all geologists. The Council desire to take this opportunity of testifying their appreciation of your efforts, and on their behalf I beg to hand you the Murchison Medal.

Mr. Ussher replied in the following words:—

Mr. President,—I sincerely thank you, the Council, and the Fellows of this Society for the honour thus conferred upon me and for the unanimity with which it has been bestowed. The work to which, Sir, you so flatteringly refer was done so long ago that this recognition is doubly grateful, as a convincing proof that my researches have not been forgotten.

My work among the New Red rocks of the South-Western Counties, begun in 1870 and completed in 1880, was inspected by my old chief, Sir Andrew Ramsay, who characterized it as "first-class work", a commendation most encouraging at the time and still a highly prized remembrance. This work has not all been officially published, even now.

The discovery of the structure and succession of the Devonian rocks would have been effected by a dear friend of mine, the late A. Champernowne, but for his untimely death in 1886. In 1888–9 I was employed in endeavouring to reconcile the different versions of Champernowne's work, with a view to publication, and I made an earnest attempt to solve the doubts which Champernowne entertained as to the relative positions of certain members of his sequence. The solution of these problems led to the establishment of the true Devonian succession in South Devon, and to the correlation of the subdivisions with those of the Continent. In this work I have been greatly assisted by Continental geologists, among whom my old friend Professor Gosselet (a former recipient of the Murchison Medal) figures prominently. The tentative application of this succession to Cornwall in 1891 was proved to be substantially correct by the subsequent work of the Geological Survey.

In conclusion, Sir, allow me to renew the expression of my thanks for the honour conferred upon me.

In handing the Lyell Medal, awarded to Charles Stewart Middlemiss, B.A., to Sir Thomas H. Holland, K.C.I.E., for transmission to the recipient, the President addressed him as follows:—

Sir THOMAS HOLLAND,—During a service of more than thirty years on the Geological Survey of India, Mr. Middlemiss has done much to advance our knowledge of the geology of that country.

He was one of the first to apply modern microscopical methods to Indian problems, and by their use in dealing with palagonite-bearing traps and the phenomena of contact-metamorphism arising from the intrusion of the Himalayan central granite, was able to make important contributions to the science of petrography. We are indebted also to him for a great extension in our knowledge of the Archæan complex in the southern and south-eastern parts of the peninsula.

In his studies on tectonic geology in the Sub-Himalaya of Kumaon, the frontier district of Hazara, and the Salt Range of the Punjab he has displayed a marked originality, and his more recent work in Kashmir has done much to elucidate the pre-Tertiary geography of Gondwanaland. His investigations of the Bengal earthquake of 1885, and his elaborate analysis of the phenomena accompanying the disastrous Kangra shock in 1905, form valuable additions to seismological records. No less has applied geology benefited by his investigations on the stability of slopes in mountainous regions.

The papers in which Mr. Middlemiss has presented his results enrich the publications of the Geological Survey of India, not only by their scientific value, but by the literary charm of his pen and by the happy facility of his pencil.

In recognition of this great record of work, the result of single-hearted devotion to his duties, I ask you to forward to Mr. Middlemiss, on behalf of the Council, the Lyell Medal.

Sir Thomas Holland, in reply, said:—

It gives me special satisfaction in this way to represent my Service in acknowledging the honour bestowed on a colleague who, by his unselfish devotion to work and his gentle disposition, has so conspicuously earned the affectionate respect of every officer with whom he has worked.

You have referred, Sir, both judicially and judiciously, to the excellent quality of Mr. Middlemiss's long record of published results; but only those of us who have been his colleagues in India can form a sufficient appreciation of his perfect freedom from personal ambition and his disinterested devotion to the science of geology.

By reason of a combination of chances such as often affects a service which is partly official and partly scientific, I have had the peculiar opportunity of discovering the fine personal qualities of Mr. Middlemiss from two distinct points of view; for I have had the pleasurable privilege of working directly under him in the field, and have had the honour also of being his official chief. Having thus seen him from all sides, I can confidently assert that Mr. Middlemiss's record of good work has no seamy side. This award will be keenly appreciated by all past and present members of the Indian Geological Survey; a referendum made to that critical community would have found Mr. Middlemiss returned unopposed.

The choice of the Lyell Medal is especially appropriate, as the chance possession in his youth of a copy of the *Student's Elements* was, as we in India know, the work which turned Mr. Middlemiss to the study of geology.

In writing from India to express his appreciation of the award now made by the Council, Mr. Middlemiss states with obvious sincerity that

"Much of the pleasure that I have derived from my geological work in this country has been enhanced by the friendly and helpful relations that have always existed between myself and my colleagues, who, I know, rejoice with me in the award".

The President then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. Richard Bullen Newton, F.G.S., addressing him in the following words:—

Mr. NEWTON,—After some years in the Palæontological Department of the Geological Survey, you were transferred in 1880 to the Geological Department of the British Museum (Natural History). During this long service in two public departments not only has your work been distinguished by care and thoroughness, but you have utilized your opportunities for making yourself well acquainted with the Gasteropoda and Lamellibranchiata, more especially of the younger geological formations. The contributions which you have thus been able to make to the palæontology of parts of Africa and Asia, in addition to your work in the British Isles, have enriched the pages of our Journal for many years. On behalf of the Council, I beg to hand you the Balance of the Proceeds of the Wollaston Fund.

In presenting the Balance of the Proceeds of the Murchison Geological Fund to Mr. Frederick Nairn Haward, the President addressed him as follows:—

Mr. HAWARD,—At a time when enthusiasm in the pursuit of proofs of human workmanship on flints has threatened to outrun discretion, you have engaged in a study of the various forms of fracture which can result from natural causes, in order to demonstrate that much of the chipping attributed by some observers to Man may have been due to natural agencies. Your minute and unbiassed investigations cannot fail to exercise a useful influence on the treatment of this speculative subject. In handing to you the Murchison Geological Fund, awarded to you by the Council of this Society, I express the hope that you will regard it as a mark of appreciation of what you have already done and as an encouragement to continue your researches.

The President then handed a Moiety of the Proceeds of the Lyell Geological Fund, awarded to the Rev. Walter Howchin, F.G.S., to Professor W. W. Watts, F.R.S., for transmission to the recipient, addressing him as follows:—

Professor WATTS,—Before leaving this country, upwards of twenty years ago, Mr. Howchin had already done useful work on the Carboniferous Foraminifera. On his arrival in Australia, he continued his studies on these organisms in the Tertiary, Cretaceous, and Permo-Carboniferous rocks. It was during the prosecution of his researches among the Permo-Carboniferous glacial deposits that he came upon widespread 'tillites' at an horizon lower than that of the *Olenellus* and *Salterella* beds of the Lower Cambrian. The glacial phenomena presented by these rocks were first described in detail in a convincing paper laid by him before this Society in 1908, although a preliminary note on their existence had been read before the Royal Society of South Australia in 1901.

In addition to his researches upon these extraordinarily interesting episodes in Palæozoic times, Mr. Howchin has done much to elucidate the complicated structure of Mount Lofty, and the general physiography of South Australia. In making the award, which I now beg you to forward to him, the Council desire to testify their sense of the great importance to geological science of the work that he has done in far-distant Australia.

In presenting the other Moiety of the Proceeds of the Lyell Geological Fund to Mr. John Postlethwaite, F.G.S., the President addressed him in the following words:—

Mr. POSTLETHWAITE,—For more than forty years your name has been associated with the geology of the Lake District, for it was in 1874 that you read a paper at Keswick on the Mines and Minerals, which was destined to develop into the useful and beautifully illustrated book reissued in third edition only last year. Though minerals and ores have claimed much of your attention, the igneous rocks with which they are so often associated have been studied in the field and described by you in the pages of our Quarterly Journal. To you also is due the credit of having helped to clear away the obscurity attaching to the age of the Skiddaw Slates by your indefatigable and successful search for fossils.

The award, which it is my privilege to hand to you, has been allotted to you by the Council in testimony of their appreciation of your work in the classic ground of the English Lake District.

The President thereafter proceeded to read his Anniversary Address, giving Obituary Notices of several Foreign Members, Foreign Correspondents, and Fellows deceased since the last Annual Meeting, including Professor H. Rosenbusch (elected a Foreign Member in 1890); Professor Anton Fritsch (el. 1897); Professor H. Credner (el. 1898); F. N. Chernyshev (el. 1909); Professor A. Baltzer (el. 1911); Professor I. Cocchi (elected a Foreign Correspondent in 1874); Lord Avebury (elected a Fellow in 1855); Professor J. Milne (el. 1873); H. B. Woodward (el. 1868); Dr. T. Anderson (el. 1890); Lord Strathcona (el. 1885); J. McMurtrie (el. 1873); Dr. H. F. Parsons (el. 1877); J. L. Lobley (el. 1865); Sir James Lamont (el. 1859); W. H. Sutcliffe (el. 1903); Dr. P. L. Sclater (el. 1878); F. J. Mitchell (el. 1859); H. K. Slater (el. 1902); and T. H. Cope (el. 1905).

As the main subject of his Address, the President referred to that part of the work of George Darwin and Wallace which bore on the history and age of the Earth, and commented on the vagueness of the evidence on which estimates of the rapidity of denudation in past times are founded. The problem of denudation was beset with difficulties, due to our imperfect knowledge of the distribution of different types of rocks and climates in primæval land-surfaces. Before attempting estimates of primæval time, it should be shown that some degree of precision is attainable in calculating the amount of denudation effected in post-Glacial times and the time required to effect it.

It was now generally possible to distinguish the features in the landscape which were due to post-Glacial erosion. River-gorges, dissected plateaus, fans and deltas of gravel were presented for consideration. In some there seemed to be a possibility of estimating the bulk of the material which had to be moved and the rapidity with which the transporting agents are working.

As an example, the gorge of the River Alyn in Denbighshire was quoted. The post-Glacial excavation was of measurable size, and its contents had been shot on to a plain in the form of a fan of measurable extent. Fans spread on the flat bottoms of valleys by tributary streams, or deltas formed in lakes, were of common occurrence. In all cases it would be of value to determine a relation between three factors, namely, the size of the fan or delta, the discharge of the stream, and the character of the ground from which the material was derived. In one case, in the Vale of Neath, the stream was carried over a railway on an aqueduct, and the amount added annually by it to the fan could be observed in its passage.

Lakes occupying hollows among Drift-mounds gave a different problem. The material accumulating in them was blown and washed by rain from the surrounding slopes.

Dammed-up rivers gave opportunities for observing the amount of material transported by rolling. Canalized rivers were not paralysed as denuding agents, but asserted themselves in time of flood. The amounts dredged at various points on the canalized channel should give an accurate measure of the activities of the river.

The distance over which rivers were now transporting material should be ascertainable by observing the composition of recent alluvial deposits. Few rolled gravel directly into the sea, for the gradients in the lower parts of their courses were too low for transportation and favoured deposition. A diagram of the Exe, Medway, and Severn, showing their gradients from source to mouth, illustrated this and brought to light interesting differences. The last two had long tidal reaches and perfectly-graded middle reaches, with sharp upturns to the source which were common to all rivers. The Exe had a comparatively short tidal reach and a more steeply and less perfectly-graded middle reach. A change in the gradient was observable where the Exe passed from Devonian rocks on to Culm Measures.

An investigation on English rivers had been proceeding for some years with the object of ascertaining (1) the discharge, (2) the suspended and dissolved impurities, (3) the rainfall, (4) the areas of the basins, and (5) the character of the rocks.

The rivers suitable for the investigation were limited to those with a single definite mouth. Fen-rivers had a number of outlets, and could not be gauged. The Exe, Medway, and Severn were selected as examples of an upland stream and of canalized lowland rivers. It was sought to establish a definite relation between the level of the water on the one hand and the velocity of the current and the amount of suspended or dissolved matter on the other hand. The results were partly in accordance with anticipation. The suspended matter was scarcely measurable until the water reached a certain level above normal, but increased rapidly for higher levels. The dissolved matter was at its maximum when the river was lowest and diminished as the level rose.

The amount of material now being rolled by the Exe was determined from records of dredgings. Rainfall was dealt with by the British Rainfall Organization, as also the methods of eliminating the error in calculating average rainfall, due to the preponderance of rain-gauges in the lower ground.

The determination of water-partings was discussed, and examples quoted where precision is not attainable.

It was concluded that, although in this country a hydrographic survey, including all the heads of this inquiry, may not be essential on the ground of utility, yet more systematic observations on the work of denudation as now proceeding are within the reach of geologists.

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.; William Hill; Clement Reid, F.R.S., F.L.S.; and Aubrey Strahan, Sc.D., LL.D., F.R.S. *Secretaries:* Herbert Henry Thomas, Sc.D., B.Sc., 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 Thomas George Bonney, Sc.D., LL.D., F.R.S.; Charles Gilbert Cullis, D.Sc.; R. Mountford Deeley, M.Inst.C.E.; James Vincent Elsden, D.Sc.; John William Evans, D.Sc., LL.B.; Professor William George Fearnsides, M.A.; Walcot Gibson, D.Sc.; Professor Owen Thomas Jones, M.A., D.Sc.; Horace W. Monckton, Treas.L.S.; Edwin Tulley Newton, F.R.S.; Professor William Johnson Sollas, M.A., Sc.D., LL.D., F.R.S.; William Whitaker, B.A., F.R.S.; the Rev. Henry Hoyte Winwood, M.A.

II.—MINERALOGICAL SOCIETY.

January 27.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

T. Crook: The Genetic Classification of Rocks and Ore-deposits. The general principles of the classification of rocks were considered, the term rock including all mineral deposits. The exact nature of genetic grouping was defined. Both rocks and ore-deposits fall into broad natural divisions in accordance with a geological grouping of formative agents and processes, the type being determined by the last operative agent or process that gave the rock its individuality. The two main groups are (1) endogenetic deposits, arising from internal causes, and (2) exogenetic deposits, of superficial origin, and these are subdivided in a consistent genetic manner. 'Sedimentary' and 'metamorphic' products cannot be regarded as constituting two independent subdivisions. An historical review of the application of genetic-geological principles to the classification of rocks and ore-deposits was included.—Professor A. F. Rogers: Lawsonite from the Central Coast Ranges of California. Crystals from new localities were described; prismatic and tabular in habit and usually small, they displayed the forms 010, 001, 011, 110.—A. F. Hallimond: Uniaxial Augite from Mull. The small, lath-shaped crystals, which seldom exceed $\frac{1}{2}$ mm. in diameter, have refractive indices *o* 1·714, *e* 1·744, specific gravity 3·44, pronounced dichroism (*o* smoky-brown, *e* pale-yellow), two cleavage directions nearly at right angles, and an extinction angle of $30\frac{1}{2}°$ on the cleavage. A chemical analysis revealed distinct differences from ordinary diopside, and the composition approximates to that of hypersthene.—H. H. Thomas and W. Campbell Smith: Apparatus for Grinding Crystal Plates and Prisms. A gun-metal cylinder with its axis normal to a triangular brass-plate, about

5 cm. in diameter, resting on three screws, one of which has a graduated head, is movable vertically along, and rotatable about its axis, and by rotation of the graduated screw the axis of the cylinder is inclined at a known angle to the grinding lap. A crystal suitably mounted is brought by means of these two rotations into any desired position, a series of chucks of different inclinations being provided for holding it. The zero position is determined optically. A graphical method of determining the requisite rotations was described.

CORRESPONDENCE.

THE NATURE AND ORIGIN OF FIORDS.

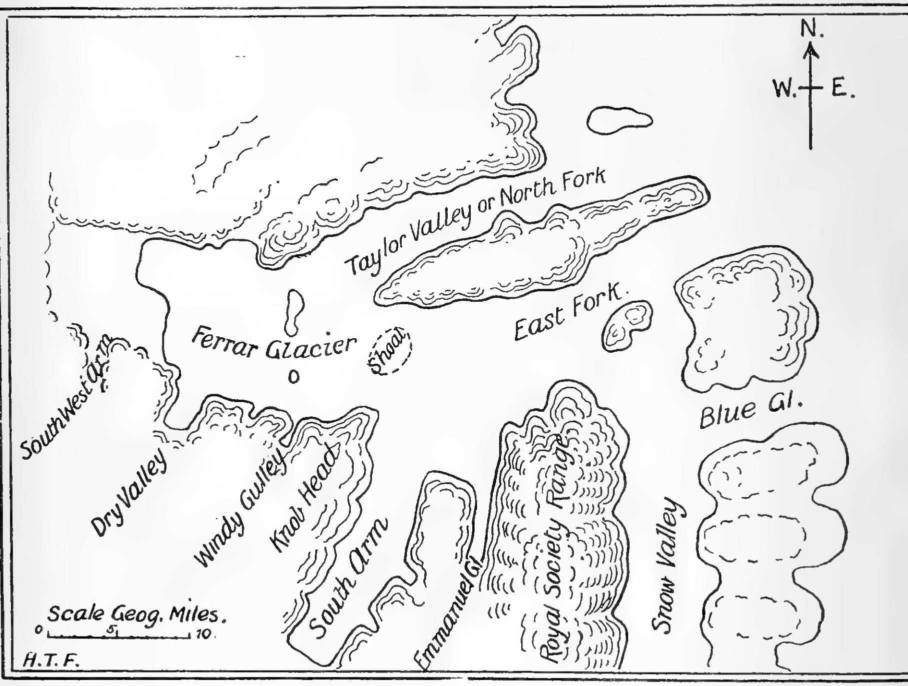
Sir,—Although Professor J. W. Gregory denies the presence of fiords in South Victoria Land in his recently published work with the above title, I feel bound to point out that *fiord-valleys* whose characteristics agree in all essentials with his fiord - valleys (pp. 17 and 19) occur, if somewhat infrequently.

The existence of fiord-valleys on this coast strengthens rather than weakens his main theme, and, as we are led to expect (p. 479), a simple foundering, such as that which has taken place in South Victoria Land, would not form a full fiord-system. In singling out only two of the many 'inlets' which indent the coast he implies (p. 370) that they are not even simple fiords. The first, Tucker Inlet, has had only its entrance fixed by ships passing along the coast, and therefore it is not likely that any branches or arms, if such exist, would be indicated on the published maps; the second, Granite Harbour, lately surveyed in detail by Mr. Debenham of Scott's ill-fated expedition, in many respects would resemble a fiord were the sea to encroach 1,000 feet or so upon the land. Likewise the Ferrar Glacier and its branches, if depressed some 3,000 feet, would provide all the essential characteristics of a fiord (pp. 66 and 385), and the accompanying sketch-map is intended to depict the coastlines subsequent to such a submergence of the valley (see p. 190).

The points outlined above should have an important bearing on the subject of glacial erosion, i.e. the erosive power of water-substance in its solid form (ice), which once again is under discussion. Professor T. W. E. David and Mr. Priestley, after boldly showing on a map (Eleventh International Geological Congress) a network of faults determining the main tectonic features of South Victoria Land, have joined the ranks of the 'Erosionists'. (I noticed that only one of the series of east and west series of faults was made to coincide with an important east and west valley.) So too has Mr. Griffith Taylor in his contribution to the narrative of "Scott's Last Expedition"; but he does not explain why the glaciers which gouged out the valleys leading into Granite Harbour did not remove Mount Suess, nor why the ice-stream which excavated Taylor Valley (the North Fork of the *Discovery* and *Nimrod* maps) did not remove the two projecting Riegeln.

During my traverse of the then unexplored Ferrar Glacier, I, like Professor Gregory (Preface), "found it difficult to determine which features were due to denudation, glacial and preglacial, and which were due to valley formation by movements of the earth's crust," and hence in my report described what I saw, but made no deductions. Now that I have gained further knowledge and experience I feel that I can take up a definite position. I hold that the great transverse valleys of Central South Victoria Land were not entrenched by glacial erosion, but are disruption clefts due to the unequal foundering of the land, the Royal Society Range having stood firm as the surrounding continent subsided.

I would go even a step further than Professor Gregory in denying the erosive power of ice as such. In the first place I agree with



Sketch-map showing shore-lines of Ferrar Glacier and its branches after a submergence of 3,000 feet.

Professor Garwood and Dr. Harker that the *corroding* action of a partially buoyed up glacier snout, which is thawing above water and melting below, is small. In the second place I do not see how *corrosion* by pot-holing (p. 407), the evidence for which is meagre, can deepen a valley indefinitely, for unless the water of the supraglacial cascade escapes as a subglacial stream *below the bed level of the valley* a pool will be created and the water in it will form a cushion, and so set a limit to the process. In the third case spur-truncation seems to me to be brought about by the action of running water more than by the rasping action of rock-charged ice. Between glacier side and valley wall a racing stream is usually to be seen, which erodes both ice and rock. The stream cannot meander away from the valley-wall, for owing to the movement of the glacier the ice is renewed as fast as or faster than it disappears, while the spurs of the hills are open to the continuous attack of the water thus trained against them. No doubt this enhanced action of the water has given rise to the seemingly contradictory conclusion (p. 431) "that glaciers have the power of cutting back spurs which is greater than that of water".

H. T. Ferrar,
Geologist to the *Discovery* Antarctic Expedition.

February 23, 1914.

OBITUARY.

SIR JOHN MURRAY, K.C.B., F.R.S., LL.D., D.Sc., Ph.D.

Born March 3, 1841. Died March 16, 1914.

A feeling of profound regret was shared by all naturalists and men of science generally at the announcement on March 17 of the sudden death by a motor accident of Sir John Murray, whose name is so intimately associated with the famous *Challenger* explorations, and to whose untiring energy and devotion we are indebted for the carrying out of the results of the work, a task which, owing to the illness of Sir Wyville Thomson, fell almost entirely to Sir John Murray. The *Challenger* sailed in December, 1872, and returned in May, 1876, bringing back innumerable pelagic and other organisms new to science. Writers of eminence in the several departments were engaged, whose labours occupied from 1880 to 1895, resulting in the production of fifty large quarto volumes admirably illustrated by maps, plates, and text-figures. This fine series of "*Challenger* Reports", thanks to the efforts of Sir John Murray and the generosity of the British Government, may now be seen and consulted in all the principal libraries and scientific institutions of the world.

Born at Coburg, Ontario, Canada (March 3, 1841), John Murray was the second son of Robert Murray and his wife Isabel, daughter of the late Thomas Henderson, ship-owner. He was educated at a public school in Canada, then in 1858 at the High School of Stirling, Scotland, and later at Edinburgh University, where he came under the influence of Lord Kelvin, Clerk Maxwell, and Professor Tait.

Sir John Murray, in addition to his administrative and editorial duties, took an active part in the "*Challenger* Reports", and contributed two large volumes summarizing the scientific results of the expedition, which occupied twenty-three years of his life. Nor was Sir John Murray's work confined to the famous *Challenger* expedition, for in 1880 and 1882 he took part in the exploration of the Faröe Channel in H.M.S. *Knight Errant* and H.M.S. *Triton.* He also established marine laboratories on the shores of the Forth at Granton and on the Clyde at Millport, Cumbrae. With his steam yacht *Medusa*, fitted with all suitable appliances, he made soundings and exploration of numberless locks and straits on the coast of Scotland. (See also his and Mr. Pullar's Bathymetrical Survey of the Scottish Freshwater Locks, 6 vols., 8vo, Edinburgh, 1910.)

In addition to his writings on the *Challenger*, Sir John Murray published in *The Depths of the Ocean* valuable contributions on oceanic life in its relation to geology; the condition of our planet in past ages; on the origin of coral reefs; on geography, oceanography, and marine biology. Sir John Murray married, in 1889, Isabel, only daughter of the late Mr. Thomas Henderson, ship-owner, of Glasgow. He leaves two sons and three daughters.

He was made a Knight of the Prussian Order pour le Mérite in 1898. He received numerous medals, and was an honorary member of a great number of British and foreign scientific societies.

JAMES McMURTRIE, F.G.S.

BORN 1840. DIED FEBRUARY, 1914.

WE regret to record the death of another excellent geologist, and valued friend, Mr. James McMurtrie, F.G.S., of 5 Belvedere Road, Durdham Park, Bristol, who passed away on February 2, in his 74th year.

Mr. McMurtrie was for forty years connected with the estates of the Waldegrave family, and was manager of their collieries at Radstock until 1902. It was from this coal-field that many of the ferns figured by Brongniart in his *Histoire des Végétaux Fossiles*, 4to, 1828, were obtained.

Mr. McMurtrie was elected a Fellow of the Geological Society of London in 1873. He was a typical Scotchman and served as President of the Bristol Caledonian Society in 1906.

Born at Dalquahrran, in the parish of Dalry, Ayrshire, McMurtrie began life under his father, who was manager of the collieries at that place. He entered for a short time upon commercial life in Liverpool, but soon removed to Newcastle-on-Tyne, becoming a mining pupil at the Towneley Collieries at Ryton, where he was articled to Mr. Robert Simpson. Having completed his articles McMurtrie (in 1862) at the age of 22 went to Radstock, Somerset. During his forty years' residence he carefully studied and mapped the coal-seams of that difficult area and collected some very fine and characteristic coal-plants which he subsequently presented to the Geological Department of the British Museum, Natural History, Cromwell Road, London.

HENRY POTONIÉ.

BORN NOVEMBER 16, 1857. DIED OCTOBER 28, 1913.

WE regret to record the death of this distinguished palæobotanist. Born in Berlin he was educated in that city and in Paris, and at the age of 21 gave special attention to the study of botany. In 1880 he was appointed an assistant in the Botanic Garden at Berlin; five years later he became Palæobotanist to the Geological Survey of Prussia; in 1891 he was appointed Professor of Palæobotany in the School of Mines, and in 1901 occupied a similar post in the University at Berlin. His *Lehrbuch der Pflanzenpaläontologie* was published during the years 1897–9, and a second edition was in preparation. He was author also of other books on recent and fossil botany, and of many important papers on fossil plants.

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STEGANOBLASTUS.

THE

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No. V.—MAY, 1914.

ORIGINAL ARTICLES.

I.—Studies in Edrioasteroidea. V. *Steganoblastus.*[1]

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

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(PLATE XV.)

Previous History.

THIS form was first made known in 1897, by the late J. F. Whiteaves, in a paper entitled "Description of a new genus and species of Cystideans from the Trenton Limestone at Ottawa" (Canad. Rec. Sci., vol. vii, No. 5, pp. 287–92). This part bears on the wrapper the date "January, 1897", which is obviously erroneous, since the author dated his own contribution "April 28th, 1897", and copies of it were first received in London on July 31 of that year.

In that paper the species received the name *Astrocystites ottawaensis*, and was regarded as "most nearly related to *Asteroblastus*, Eichwald, and . . . probably referable to the same family". In a letter sent to Dr. Whiteaves by the next mail, I pointed out difficulties in this interpretation of the structure, as well as difficulties in the name *Astrocystites.* "You can," I wrote, "hardly have been aware that Haeckel, in 1896, separated *Asteroblastus tuberculatus* of Schmidt from *A. stellatus* under the new generic name of *Asterocystis.*" I further pointed out that the termination *-ites* was frequently dropped, and was no real distinction; also that ἀστήρ and not ἄστρον was the correct word to use in composition for the sense intended by Dr. Whiteaves. A change of name therefore not only would avoid confusion but seemed to me justified. Dr. Whiteaves accepted my view, and in a "Postscript" (tom. cit., p. 395, January 7, 1898) published the name which I suggested to him—"*Steganoblastus*, from στεγανός, closely covered, with reference to the large covering plates and covered mouth." In this Postscript he inadvertently alluded to the species as *Steganoblastus canadensis* instead of *S. ottawaensis.*

In consequence of my remarks on the structure, Dr. Whiteaves kindly lent me the two specimens belonging to the Geological Survey of Canada, which, with an imperfect specimen lent me by Mr. Walter R. Billings, made up all the known material. The first results of my examination were summarized in Lankester's *Treatise on Zoology*, vol. iii, pp. 209–10, text-fig. vii (1900), where I founded for the reception of this genus the Family Steganoblastidæ of the Class Edrioasteroidea.

[1] Study IV appeared in the Geol. Mag. for March and April, 1914.

In September, 1906, Dr. Whiteaves reprinted his original description, followed by a complete extract from the *Treatise*, in *Palæozoic Fossils*, vol. iii (pp. 316–21), published by the Geological Survey of Canada. My drawings of *Steganoblastus* were also among the very large number of text-figures which Messrs. Delage and Hérouard paid me the great compliment of reproducing in reduced facsimile in their *Traité de Zoologie concrète*, tome iii, "Les Echinodermes" (pp. 415, 416, Paris, March 30, 1904). The Family Steganoblastidæ is accepted by Dr. F. Springer in the second edition of Eastman's *Zittel* (1913).

The present paper gives the evidence on which my textbook account was based.

Material.

The specimens are the three syntypes of Whiteaves, and may be distinguished as A, B, and C. All were obtained from the Trenton Limestone at Division Street, Ottawa. The precise horizon has nowhere been stated.

Specimens A and B were collected by Mr. John Stewart in 1886, and are in the Victoria Memorial Museum, Ottawa. Specimen C was collected by Mr. Walter R. Billings, in whose possession it remains.

A is an almost perfect theca with two columnals. It is the original of Whiteaves' figs. 1 and 2, and of Pl. XV, Figs. 1, 3, 4, 6, 7, in the present paper. It is hereby selected as the holotype.

B is a theca crushed in the left anterior interradius and adjoining radii, with portions of three columnals. It is the original of Whiteaves' fig. 3, and of our Pl. XV, Figs. 2, 5.

C is a much broken and crushed theca with no columnals.

"All three of these specimens, when found, were," says Whiteaves, "almost completely covered with a very tenacious shaly limestone." This had been for the most part skilfully removed before the specimens were sent to me, but the pores and the outlines of the plates were still obscured.

General Description.

The chief features can readily be gathered from the slightly restored figures 1 and 2, here reprinted, with slight modification, from the *Treatise* (1900).

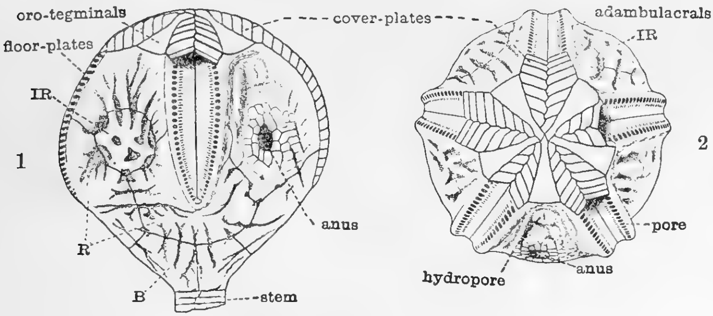
The most obvious difference from Edrioasteroidea belonging to the Family Edrioasteridæ lies in the Stem of normal pelmatozoan character. This supports a Theca of regular pear shape.

The Theca consists, as in other Edrioasteroidea, of two systems of plates: (1) an adoral system, (2) an adapical system. From the tegminal region above the peristome, the Adoral System radiates in the form of five subvective grooves, passing straight along the perradial meridians, to a level almost exactly two-thirds of the way down the long axis of the theca. From the stem, at the opposite pole, the Adapical System spreads upwards, supporting and passing in between the five grooves, to abut finally on the interradial elements of the tegmen. In one of the interambulacral areas of this system, lies the anus, marking the posterior interradius.

Description of the Specimens.

The measurements of the piriform theca in specimen A are approximately: height, 19·5 mm.; greatest diameter, 18 mm., this being at 8·5 mm. from the summit.

Except for the tegminals and cover-plates, all the thecal elements are closely united, so that it is difficult to distinguish the sutures. This difficulty is enhanced by the pitted ornament of the surface, and by the very deep folding of the plates which form the adapical system. On the other hand, as one removes the tenacious black matrix from the depths of the folds, one realizes that they represent a system of rhomb-ridges and axial folds on the plan so common in Pelmatozoa; and, remembering that in such cases the folds are at right angles to the sutures, one is able with somewhat greater confidence to trace the limits of the plates. In some cases it may be that the arrangement of the folds indicates rather the original constitution of the young individual (or of its ancestor) than any actual



Steganoblastus ottawaensis.

Fig. 1. Restored view of theca from left posterior interradius.

Fig. 2. Restored view of oral surface.

Both drawings are based mainly on specimen A. × 2 diam.

separation of plates in the adult. It seems plain that the tendency of the species is to fuse the originally indefinite smaller plates into a few larger plates of definite arrangement (cf. Text-fig. 3).

The plates distinguishable in the adapical system (Text-fig. 1) are five basals, five radials, and in each interradius a varying number of interambulacrals. From a strictly morphological standpoint, one should perhaps also include in this system the floor-plates of the subvective grooves.

The Basals are of the pentagonal shape usual in normal crinoids. As the following measurements from specimen A show, they are a little lower on the posterior side of the theca, owing to the space required by the anal plates. The measurements are in millimetres and are taken along the surface of the theca.

	l. ant.	l. post.	post.	r. post.	r. ant.	ant.
Height of basal	5·6	5·5	5·1	5·2	5 7	
Height of interbasal suture	4·6	4·0		3·5	4·2	4·25

The Radials are of the roughly pentagonal shield-shape usual in normal crinoids and in blastoids. Since they have no brachial facet, but are notched for the excavation of the subvective grooves, they more closely resemble the radials of blastoids. The basi-radial and interradial sutures can be traced without excessive difficulty; the lengths of the latter, in the case of the anterior radial of specimen A, are left anterior 3·5 mm., right anterior 4 mm.

From the top of the interradial sutures, the shoulders of the radial slope upwards towards the subvective groove, and the sutures bounding them can be traced for some distance. The point at which they meet the flooring-plates of the groove cannot, however, be distinguished, owing to the close union of the various plates in the neighbourhood of the groove. Estimated roughly, for the anterior radial as before, the level of the top of the radial would be about 5 mm. from the lip, or distal end, of the groove; and the distance of the lip from the lower apex of the radial is about 4·1 mm.

The rhomboidal area above the shoulders of the radials and between the grooves is filled with Interambulacral plates. The precise number and arrangement of these varies in the different areas, and in all except the posterior area their outlines are hard to see (Text-fig. 3). To judge from the folds, three or four small plates have joined in the centre of each area, except the posterior, to form a relatively large plate of somewhat swollen appearance (IR). This plate rests on the radials, and other smaller plates lie between it and the grooves.

The posterior area, which is more swollen and a trifle wider than the others, measuring almost exactly 10 mm. from lip to lip of the bounding grooves, is filled with a larger number of plates. Except near the boundaries of the area, these are more loosely united, so that the sutures are readily seen. About the centre of this area in specimen A the plates are rather sharply depressed; but in B the corresponding depression is very slight, so that it has here proved easier to remove the matrix, and thus to disclose seven plates converging to a point, where doubtless was the vent. These seven Circumanal plates are surrounded by about fifteen other Periproctal plates, equally well defined, very diverse in shape but never long and tapering. Outside these again come plates less well defined and therefore less easily counted, but in total number about nine, one being interradial and resting on the radials, and four bounding the sides of the periproctal area and meeting above it in an interradial suture. The twenty-two periproctal plates are but faintly pitted, and each has an equably swollen surface. The nine bounding interambulacrals, however, are coarsely folded on their abanal margins, and the folds meet similar folds from the radials and from the adambulacral plates.

By Adambulacral plates I mean those which lie between the last set of plates and the grooves; but whether they are really distinct from the floor-plates of the grooves is uncertain. To this point we shall recur.

At the adoral end of the interambulacral area there lies in the posterior interradius, and apparently in the other interradii, a single plate, continuous with the adambulacral series, and abutting above on the corresponding oro-tegminal. In the posterior interradius this plate occupies a larger area than in the others, and is much more swollen. Close examination under suitable illumination detects in this plate, in all three specimens, a meridional dark line. This is not a suture, for it is waved and does not reach the edges of the plate. It may represent the Hydropore.

The Ornament of the adapical system consists of the axial folds already mentioned, and of a number of pits.

The Axial Folds in the lower, proximal or adcolumnal region of the theca are fairly regular. From the lip of each radial there run four main ridges, one pair horizontally to the lips of the adjacent radials, one pair downwards to the middle of the base of the adjacent basals. These main ridges thus enclose triangular spaces, namely an almost equilateral triangle bounded above by the horizontal ridges, and interradial in position; an acute-angled triangle with its base on the columnar suture, and radial in position. The interradial triangle encloses a smaller, less regular triangle of ridges. The radial triangle encloses two shorter ridges also springing from the base and meeting at a wider angle (*circa* 90°) at about one-third the height of the radial triangle itself. The triangular interambulacral area, above the main horizontal ridge, contains ridges crossing the sutures of the various plates already described as interambulacrals and adambulacrals.

The folds between the ridges are very deep, especially in the interambulacral area, notably a fold just below the adoral interambulacral (Text-fig. 3). The removal of the matrix from these is extraordinarily difficult, and has therefore only been accomplished in one or two places. The operation led to no discovery of pores or any system of respiratory folds, and it may be inferred that the sole effect of the folding is to endue the theca with a quite exceptional rigidity.

The Pits cover the whole outer surface of the theca, including all the elements of the adoral system (Pl. XV, Figs. 2, 3). They have in many cases been worn away from the more prominent parts, either in the process of cleaning or, as there is some evidence to show, before the fossil was embedded in the matrix. They seem to lie even in the depressions of the folds, although not quite so well marked there. The pits seem to have been set most closely on the cover-plates and tegmen, and in consequence may there assume a more hexagonal outline. Elsewhere they are more circular. They vary in size, but have as a rule a diameter of about ·2 mm. Though they have no definite arrangement, they tend to lie along the edges of the cover-plates and along the sides of the larger folds. Occasionally there is a tendency to similar seriation at a definite angle to the sides of the grooves, as though marking the original adambulacral plates. These structures are pits, not pores, for one cannot imagine pores on cover-plates, and in any case they disappear entirely when worn down. No definite structure can be distinguished in them, but their complete resemblance to the spine-pits of Asteroidea and the lack of any other explanation render it highly probable that they lodged spines.

The Subvective System consists of five broad radial grooves leading to a subtegminal mouth. The grooves are bounded by Floor-plates, one series down each side of a groove. The two series meet along the perradius in a distinct straight suture. In each series the floor-plates are united by a very close suture, or are even fused. The sutures can most readily be detected at the distal end of the groove, near the lip (Pl. XV, Fig. 3); but their former presence is clearly marked all the way up by a series of pores, similar to the pores between the floor-plates (so-called ambulacrals) of ordinary Asteroidea, and markedly resembling those in *Edrioaster*. That these structures are pores is proved, not merely by this external resemblance, but by distinct signs of their passage through the test wherever that is broken or ground away. The pores have an elongate-ovate outline on the surface, the broader end lying just below the edge of the groove, in other words just below the attachment of the cover-plates. The narrower end points towards the perradius, and merges into the suture between the floor-plates, which in its turn dies away before joining the perradial suture.

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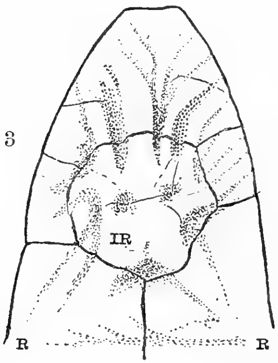

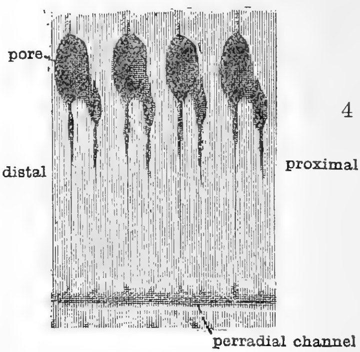

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Steganoblastus ottawaensis.

FIG. 3. An interradial area of specimen A, to show the direction of the folds, and the occasional traces of sutures at right angles thereto. × 4 diam.

FIG. 4. Portion of the side of a subvective groove, to show the pores between the floor-plates, and the depressions on the floor-plates. × 16 diam.

In tracts that have not been so well cleaned from matrix as others there occasionally appears to be another series of smaller piriform pores, between the others, and nearer the perradius (Text-fig. 4). Further cleaning, however, shows that these are not pores but depressions. Each such depression is moreover connected with the pore on its distal side by a faint groove sloping downwards from the main pore to the piriform depression.

Below the pores and the piriform depressions, that is to say nearer the perradius, is a slight swelling of the groove-floor, so that a faint rounded ridge separates the poriferous tract from the smooth floor of the groove. In other words, there is a perradial channel. The sutures continuing the pores, and the channels continuing the piriform depressions, cross this ridge at right angles, and so break it up into a row of rounded eminences, producing a toothed appearance.

At the distal end of the groove the floor-plates rapidly decrease in size, and this series is rounded off before the actual lip of the groove is reached. The distance between the end of the floor-plates and the lip seems to vary in the different radii. That in which best results have been obtained by preparation is the anterior groove of specimen A (Pl. XV, Fig. 3), but this is confirmed by other grooves so far as it has been possible to clean them. That the distal end of the groove was quite free of floor-plates is proved by the continuation of a double row of pits over the lip and along the middle of the groove, up to the end of the floor-plates. The sutures bounding these terminal floor-plates are distinct all round, and the floor-plates are seen resting on the grooved surface of the radial. Apparently, however, the radial does not actually pass right under the floor-plates, but is cut away beneath their adradial region, so that the pores between the floor-plates pass through into the thecal cavity.

The floor-plates in this part of the groove at any rate appear to have their outer boundary at the level of the pores. Owing to the close union of the floor-plates, not only *inter se*, but also with the radials and adambulacrals, it is impossible to trace any bounding suture along the edges of the groove. It seems, however, a legitimate inference that a generally similar relation of the floor-plates to the adjacent thecal elements prevails, or did in earlier stages prevail, all the way up the groove; at all events, it is clear that the floor-plates and adambulacrals are independent morphological elements, and this is a point of much theoretical importance.

At the distal end of the groove it is plain that the floor-plates of one side alternate with those of the other side.

The Cover-plates are best preserved in specimen B (Pl. XV, Figs. 2, 5; Text-fig. 5). In no case are they retained as far as the distal end of the groove, but there is no reason to doubt that they were continuous from the tegmen to the extreme end of the floor-plates. In the upper half of the right anterior groove, starting about one plate below the distal end of the oro-tegminal, there are nine cover-plates in a length of 5 mm. The proximal of these plates has a length of 2·5 mm.; the distal one a length of 1·8 mm. Nearer the oral pole the cover-plates are more irregular in shape and size, especially in this r. ant. radius of this individual. Over the greater part of the groove the cover-plates alternate regularly and meet in a zigzag suture; but at the proximal end smaller plates may be intercalated along the middle line. In specimen A there are no such intercalated plates, but the median suture in the proximal region becomes curved and interlocking (Text-fig. 6).

The relation of the cover-plates to the floor-plates appears to be quite regular. There is a cover-plate to each floor-plate, and, so far as can be ascertained after prolonged preparation and study, the sutures between the cover-plates coincide with those between the floor-plates. Thus the pores, which, as already stated, lie just below the attachment of the cover-plates, open under the sutures as in *Edrioaster*.

The thickness of the cover-plates about half-way down the r. ant. radius of specimen B is not more than ·35 mm. In many cases the cover-plates have been pulled or pressed down into the groove, but when preserved in what would seem to be their normal position they form a prominent rounded arch over the groove. The sutures between adjacent cover-plates, as well as the median suture, are slightly depressed and bordered by spine-pits. The suture between the cover-plates and the adambulacrals is flush, and the curve of the cover-plates passes over, though with a distinct bend, into that of the adambulacrals. The suture is not a straight line, but a series of curves, the convex outer edges of the cover-plates fitting into slight concavities in the adambulacral margin. The position and number of the axial ridges on this margin indicate that the original adambulacral elements coincided in number but alternated in position with the cover-plates, and therefore also with the floor-plates. This suture, then, is essentially a zigzag suture between two sets of alternating

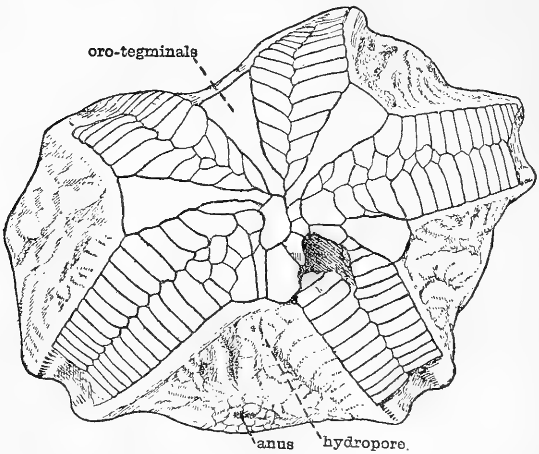


FIG. 5. *Steganoblastus ottawaensis.* Specimen B viewed from above, for comparison with Pl. XV, Fig. 5. × 4 diam.

plates. In consequence of this arrangement, one would expect to see along the edges of the groove, when the cover-plates are removed, a series of depressions or facets for the reception of the cover-plates. Unfortunately the edges have in nearly every case been worn enough to remove all trace of these very faint depressions, and it has only been by dissecting away some cover-plates at the end of the r. ant. ray in specimen B that I have been able to distinguish anything of the kind.

The Tegmen is best studied in specimen A (Pl. XV, Fig. 7; Text-fig. 6). Here the cover-plates are more regular than in B, and the arrangement of the whole follows an obvious symmetry, which, from its resemblance to that in other Pelmatozoa, must be regarded as the normal. In addition to the cover-plates, the tegmen contains only five plates, which have already been alluded to as the oro-tegminals. These abut by their distal broader ends on the inter-ambulacrals, and gradually narrow as they pass, between the converging and narrowing series of cover-plates, towards the oral pole. As is usual in Pelmatozoa, only three of them meet there: the posterior and the right and left anterior. There is, however, a difference from the usual plan in that these three can scarcely be said to meet in a triradiate suture; but the posterior plate passes between the other two and with its pointed apex actually touches the proximal cover-plate of the anterior radius, so that in this individual the two anterior oro-tegminals do not touch one another as is customary and as they do in specimen B.

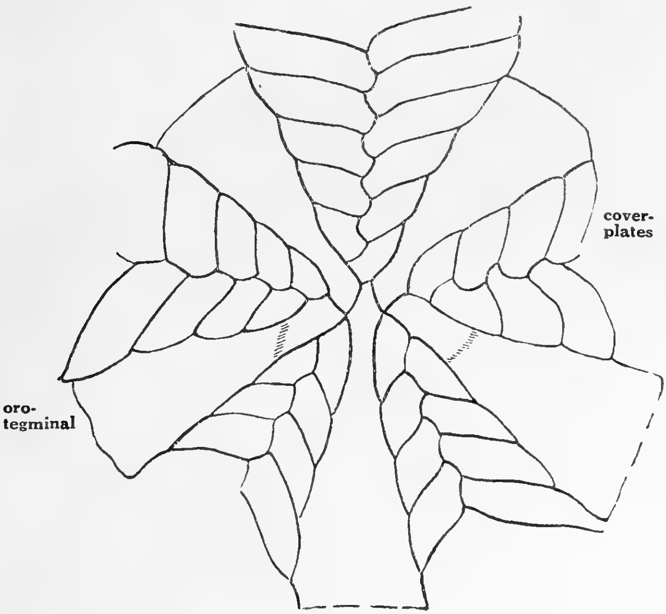


FIG. 6. *Steganoblastus ottawaensis.* Exact drawing of the sutures in the tegmen of specimen A. × 8 diam.

These three oro-tegminals have the same general shape. Each tapers gradually as the subvective grooves bounding it converge, then, as the grooves are rounded off, it expands, and again tapers rapidly to a sharp point, thus resembling a spear-head. Each of these three plates appears to be one continuous element, from the pointed apex to the broad straight base.

The two other oro-tegminals, the r. and l. post., are of the same general shape, except that they do not end in a spear-head, but in an oblique suture, abutting on the adjacent side of the spear-head of the r. and l. ant. oro-tegminal respectively. At the extreme end of this suture they may just touch the post. oro-tegminal. It is not so certain that these two plates are continuous elements. They seem to be crossed by an obscure oblique suture at the level of the second cover-plate of the adjoining grooves. It is not impossible that the proximal portion of each of these plates may represent the proximal cover-plate of the l. ant. and r. post. grooves respectively. Those are the grooves to which the supposed cover-plates would naturally belong, in spite of the asymmetry involved.

The tegmen of specimen B is so much more irregular and asymmetrical that it cannot be described in detail. The r. and l. ant. oro-tegminals have the spear-head end. The proximal end of the l. post. oro-tegminal is almost squeezed out of existence between the contiguous grooves. The r. post. oro-tegminal is transversely divided, and its proximal portion is nearly as large as the distal portion and swells out to almost the same width. The post. oro-tegminal is also divided transversely, and its distal portion is again split by meridional sutures into three elongate plates.

The Stem appears to have had a circular section, though in both A and B it is slightly crushed. The diameters in B are 5·2 mm. and 3·75 mm., giving a mean of 4·47 mm. The lumen in B has diameters *circa* 2·5 mm. and 1·75 mm., giving a mean of *circa* 1·9 mm.

The columnars are irregular plates, differing considerably in height and width, but tending apparently to form pentameres alternating about more or less radially disposed sutures. In the post. interradius of A the combined height of four such pentameres is 1·6 mm.; these alternate with three pentameres in r. post. IR having almost the same height. In the l. ant. IR of B the combined height of three pentameres is 2·7 mm., and in post. IR two pentameres have a combined height of 1·8 mm.

There seem to be traces of spine-pits on the pentameres.

Relations of *Steganoblastus.*

The meanings of all the structures that have just been objectively described will have to be discussed in a later paper. Here it is only the immediate conclusions that can be drawn.

First, the absence of brachioles, inferred from the lack of brachiole-facets and the presence of large cover-plates, proves that *Steganoblastus* is not a blastoid, not even one of the Protoblastoidea, as was at first supposed. It also proves, if proof be needed, that it is not one of the Cystidea Diploporita.

Secondly, the structure of the subvective groove, with its floor-plates and cover-plates, and its pores between the floor-plates, is paralleled by Edrioasteroidea alone among Pelmatozoa, and in that Class most closely by *Edrioaster*, though there are minor differences.

Thirdly, the presence of a stem, and the enhanced pentamerism of the thecal structures thereby induced, render it impossible to place *Steganoblastus* in the Family Edrioasteridæ. It has therefore been necessary to establish for it the Family Steganoblastidæ (*Treatise*, 1900, p. 209).

EXPLANATION OF PLATE XV.

Steganoblastus ottawaensis.

FIG. 1. Specimen A, from the posterior interradius, showing periproctals and, above them, the supposed hydropore.
,, 2. Specimen B, from the posterior interradius, showing the same features.
,, 3. Specimen A, the lip of the anterior subvective groove, showing pores, adradial suture, and spine-pits. For exigencies of lighting, the perradius is sloped downwards from right to left. × 5 diam.
,, 4. Specimen A, from the right anterior interradius.
,, 5. Specimen B, adoral view; compare Text-fig. 5.
,, 6. Specimen A, adapical view.
,, 7. Specimen A, adoral view; compare Text-fig. 6.

All the figures are from photographs by Mr. H. G. Herring, and all, except Fig. 3, are enlarged 3 diameters.

The Text-figures are based on pencil drawings by Mr. G. T. Gwilliam.

II.—THE ZONES OF THE BEAUFORT BEDS OF THE KARROO SYSTEM IN SOUTH AFRICA.

By D. M. S. WATSON, M.Sc., Lecturer in Vertebrate Palæontology in University College, London.

PROFESSOR H. G. Seeley, in his well-known paper on *Pariasaurus Baini*, incidentally mentioned that the Beaufort Beds, in which it was found, could be divided up into zones on the evidence of the reptiles they contained. Dr. R. Broom, following out this suggestion, went further and divided them into the

Cynognathus
Procolophon
Lystrosaurus
Cisticephalus
Endothiodon
Pariasaurus
} Zones.

This division is perfectly correct and cannot at present be improved upon, but beyond saying to which zone all the species which he recognized as distinct belong, Broom has never offered any evidence in support of it or indeed explained the real meaning of the division.

During my visit to South Africa I had the good fortune to collect from all these zones, and propose in this short paper to explain the evidence I collected and then to show that from the evidence of specimens in museums it is possible to construct a map which is self-consistent.

The three lowest zones are best seen round Beaufort West. Beaufort West stands on the *Endothiodon* zone, and to the south there is a great expanse of slightly rolling country, the Gouph, which is obviously composed of rocks lying below those on which the town is built. To the north the magnificent escarpment of the Nieuveld rises about 3,000 feet above the plain.

The beds which form the Gouph have been very extensively collected from by T. Bain, H. G. Seeley, The Survey, R. Broom, J. H. Whaits, and the author. They yield several species of Pariasaurs, none of which have an armour more extensive than that of *Pariasaurus Baini* as described by Seeley, that is, they have only a few small scutes round the neural spines of the dorsal region. Less common are the remains of Deinocephalia, both Tapinocephaloids and Titanosuchia and many diverse types of Therocephalia. Small Dicynodons occur in considerable numbers, but no large forms of Anomodont have ever been found, and the beds have been so thoroughly searched that their absence or excessive rarity is assured.

The *Endothiodon* beds, which are seen in the field to follow those of the *Pariasaurus* zone, have been searched by T. Bain, very largely by J. H. Whaits, and to a much less extent by the author. They have never yielded any Pariasaurian remains (except a very small femur) and no Deinocephalians. There are many Therocephalia, particularly Gorgonopsids, including *Gorgonops torvus*. There are numerous large Endothiodons, and all the Dicynodons are very small.

At the top of the Nieuveld escarpment, for example at Kuils Poort Nek, about 12 miles north of Beaufort West, there is a fauna, collected at various places along the escarpment by T. Bain, H. G. Seeley, R. Broom, The Survey, J. H. Whaits, S. H. Haughton, and the author, which has as its commonest and most striking constituent large Dicynodons, i.e. types with a skull length of 25 cm. or more. There are also Therocephalia and Gorgonopsids, quite different from those found below, and the much armoured Pariasaurians of the genus *Propappus* occur in considerable abundance. Judging from this district, which has been so extensively worked as to afford most satisfactory evidence, the zones are characterized by the following features:—

The *Pariasauras* zone, by the occurrence of large, slightly armoured Pariasauria and Deinocephalia and the absence of any large Anomodonts.

The Endothiodont zone is characterized by the occurrence of *Endothiodon* and other large Endothiodonts and peculiar Gorgonopsids, and by the total absence of large Dicynodons.

The *Cisticephalus* zone is characterized by the presence of many large Dicynodons and *Propappus*, and other much ornamented Pariasaurs and the absence of any large Endothiodonts.

The three upper zones can only be studied in the east of Cape Province. Round the towns Aliwal North and Burghersdorp the *Cynognathus* zone is very well exposed, and has been collected from by A. Brown, R. D. Kannemeyer, R. Broom, and the author. It yields a fauna the most abundant constituents of which are the large Dicynodonts of the genus *Kannemeyeria*, Cynodonts, particularly those of the family Cynognathidæ, and the Thecodont *Erythrosuchus*.

Passing north-westward of the rich locality of Winnaarsbaken at the farm Klip Kuil, a bed of extremely hard sandstone with clay galls and fragments of bone is clearly seen to dip under the *Cynognathus* beds. In this bed I found fragmentary limb-bones apparently of *Lystrosaurus*, and two complete maxillæ and a dentary of *Procolophon trigoniceps*. In the river which intersects this bed and about 200 yards below in a bed of sandstone about 100 feet below that which contains *Procolophon*, I obtained *Lystrosaurus* remains,

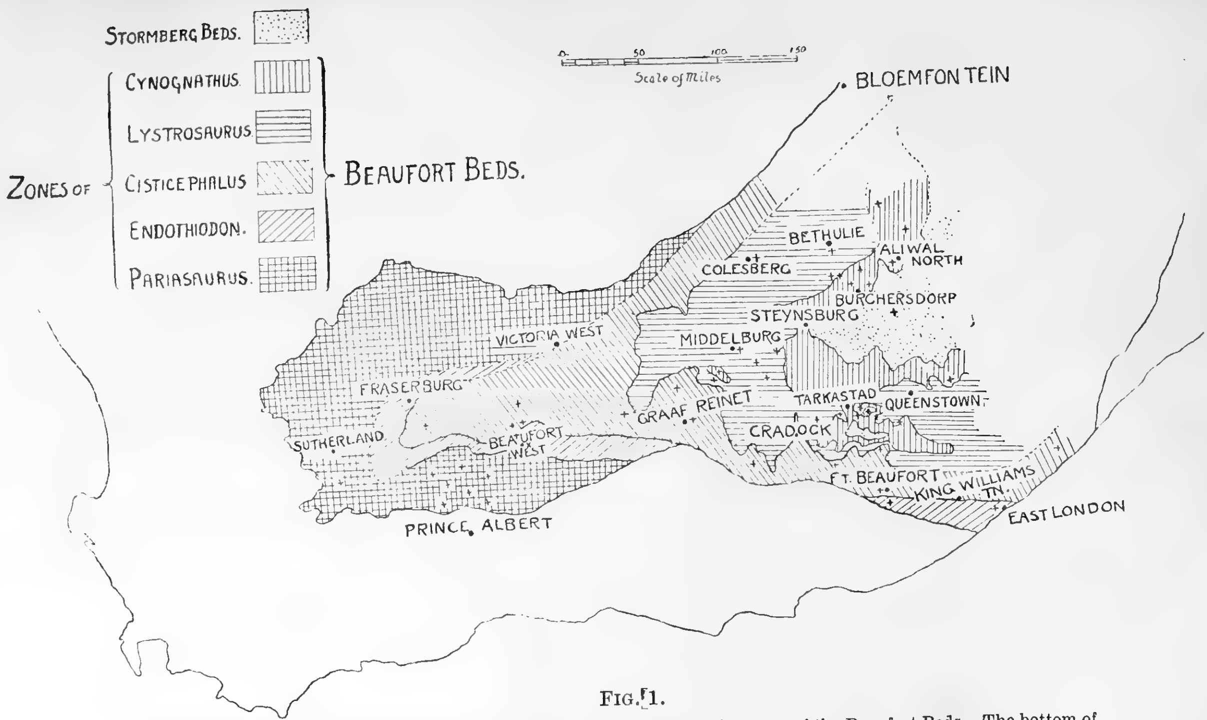


FIG. 1.

Geological Sketch-map of South Africa to illustrate the distribution of the zones of the Beaufort Beds. The bottom of the Beaufort Beds is copied from Rogers & Du Toit's map on the geology of Cape Colony.
+ Crosses are selected fossil localities, each yielding fossils of the zone in which they lie. The *Procolophon* zone is represented by the line between the *Lystrosaurus* and *Cynognathus* zones.
Judging from this map it is not improbable that there should be an exposure of the *Endothiodon* zone south of Pearston, but I know of no field evidence of its occurrence.

one skull being apparently *L. curvatus* (Owen). Further to the west, at Venterstad and Bethulie Bridge, *Lystrosaurus* again occurs, specimens being in the British and Albany Museums.

About 80 miles south of Burghersdorp, in the district round Tarkastad, I again obtained clear evidence of the order of superposition of these three zones. In the Field Cornetcy Upper Zwaart Kei of District Queenstown there is a hill, Tafelberg, the watercourses on the sides of which give excellent sections. At two localities, Haslop Hill to the north-east and Donnybrook to the south-west of this hill, I obtained *Procolophon* at nearly the lowest level explored. This reptile occurs in a thin zone in the great mass of deep-red mudstone which forms all the lower part of the hill.

On the farm Tentergate, which is on the west side of Tafelberg at a horizon about 500 feet above the *Procolophon* zone of Haslop Hill, I found in a thin sandstone a broken dentary of *Tribolodon frerensis*, the type-specimen of which was found by Professor Seeley in the *Cynognathus* zone of Lady Frere. The upper part of Tafelberg is composed of grey shales and yellow-grey sandstones, which are lithologically similar to the Molteno Beds. In the Albany Museum there is a dorsal vertebra of a Dinosaur collected by Mr. D. White at Tafelberg; as no Dinosaurs have ever been found in the Beaufort Beds, this affords very strong evidence that these grey beds are really of Molteno age. About 20 miles west of Tafelberg, in the lowest beds exposed in the farm Newtondale, I obtained *Lystrosaurus declivis* (?) in a deep-red sandstone and fragmentary *Lystrosaurus* remains in a yellow sandstone. These beds are the lowest of those occurring on this farm, and are clearly seen in the field to lie below the *Procolophon* zone of Haslop Hill. The only common animal of the *Procolophon* zone is *Procolophon* itself.

The *Lystrosaurus* zone is characterized by that animal, which occurs almost to the exclusion of other forms; there are in the British Museum some peculiar large *Dicynodon* skulls from Bethulie which seem to have come from this zone.

The *Cynognathus* zone is sharply marked by *Kannemeyeria*, Cynognathids, and *Erythrosuchus*.

Accepting the possibility of identifying these zones by the facies of the fauna they contain, a presumption which is justified by all experience and by the great length in time of the zones (the six cover the entire interval from low in the Permian to near the top of the Trias), it is easy by determining from specimens in museums the horizon of a sufficient number of localities to construct a geological map. This is done in Fig. 1 (p. 205), where the crosses represent some known fossil localities almost all represented in the British Museum. I do not intend to give a list of these localities and the fossils from them, because it is difficult to do so usefully without a systematic revision of the South African fossil reptiles. The more important and critical localities are discussed below.

The *Procolophon* zone is so thin that it cannot be separately represented, but is indicated by the line of junction of the *Lystrosaurus* and *Cynognathus* zones. *Procolophon* has been found at Whittlesea and Donnybrook, Queenstown District; Haslop Hill, District Tarka; Fernrocks, near Tafelberg Station, District Middelburg; Klip Kuil, District Albert; and at a locality on the Orange River a few miles west of Aliwal North. It also occurs in the Orange Free State. These localities fix the line with some accuracy and give the bottom of the *Cynognathus* zone, the upper limit of which is the bottom of the Molteno Beds, whose outcrop has been partly mapped by the Survey and is obvious from their marked lithological characters. The field evidence seems to show that the upper part of the Great Winterberg is composed of Molteno Beds formerly continuous with those of Tafelberg. The area of *Cynognathus* beds north-west of Graaf Reinet depends on the type-specimen of *Cynochampsa laniaria*, Owen, from Rhenosterberg. This specimen is quite certainly a Cynognathid, almost certainly a Diademodon. The most northerly *Cynognathus* zone locality which I know is Smithfield, from which the British Museum has *Erythrosuchus*.

The distribution of the *Lystrosaurus* zone is well fixed by the occurrences at Klip Kuil, Colesberg, round Middelburg, and Newtondale in Tarka. North of Fort Beaufort its distribution on the map depends on a thick mass of light-yellow sandstone which I believe to belong to this zone. Large Dicynodons indicating the *Cisticephalus* zone are found at many localities round Fort Beaufort. The occurrence of the type-specimen of *Pariasaurus* at Blinkwater suggests the occurrence of the zone of that name, but specimens in the British Museum which I have strong reasons for believing to belong to that type-specimen are of a type which would now be called *Propappus*, a typical *Cisticephalus* zone form.

The occurrence of the type-specimen of *Gorgonops torvus* at "Mildenhalls", which is probably the farm now owned by the family of that name a few miles south of Fort Beaufort, shows definitely the occurrence of the *Endothiodon* zone, for another and absolutely identical individual has been found in the zone at Beaufort West. The small Endothiodonts found at East London suggest the same horizon, though they might be of *Cisticephalus* age.

The *Cisticephalus* locality north of Bedford is on the Kagaberg, where *Dicynodon tigriceps* occurs, that near Aberdeen depends on the type-specimen of *Platypodosaurus robustus*, Owen, from Camdebo. Large Dicynodons probably of this horizon in the Bloemfontein Museum come from the Modder River about 20 miles east of that town. Similar but very fragmentary remains have been obtained at Senekal and Harrismith.

The typical large lightly armoured Pariasaurs of the zone of that name have never been found except in the Gouph. The Deinocephalian *Moscops* comes from Dams Laagte, south of Sutherland. As the large bones of these reptiles when weathered out are only very slowly destroyed and are very conspicuous objects, the fact that they have never been found elsewhere gives good reason for believing that this zone either does not occur out of this district or, much less probably, is not fossiliferous.

The map constructed in this way from many more localities than those actually marked is self-consistent, and I think does make an approximation to the real general distribution of these zones in those regions, a wide strip between Aliwal North and Fort Beaufort, and the district round Beaufort West, of which I have a personal knowledge. It is, I hope, fairly satisfactory, but the country between Graaf Reinet, Beaufort West, Victoria West, and Colesberg has as yet yielded so very few fossils as to be in the last degree speculative. The Free State fossils are so few and so badly localized that that province is practically a *terra incognita*. The most interesting feature is the occurrence on Harrismith commonage of *Lystrosaurus*, a large *Dicynodon*, and typical Deinosaurs of the Red Beds of the Stormberg Series, a fact which seems to indicate plainly a thinning out of the *Cynognathus* zone and Molteno Beds, and that overlap of the Stormberg Beds into older rocks which we know to have occurred in that direction. There is evidence of the occurrence of *Cisticephalus* and *Lystrosaurus* beds in Natal.

The map brings out clearly the fact that the Karroo rocks lie in a basin formed by two shallow synclines whose axes, running approximately east and west and north and south, meet in the Transkei, and that they dip at an extremely low angle to the east and the south respectively.

I have in connexion with this paper to thank the Trustees of the Percy Sladen Fund, who assisted me to visit South Africa, many farmers in Cape Colony too numerous to mention separately, and particularly my friends Dr. R. Broom and the Rev. J. H. Whaits, whose knowledge is invaluable.

III.—Periods of Dreikanter Formation in South Notts.

By Professor H. H. Swinnerton, D.Sc., F.G.S., F.Z.S.,
University College, Nottingham.

(PLATE XVI.)

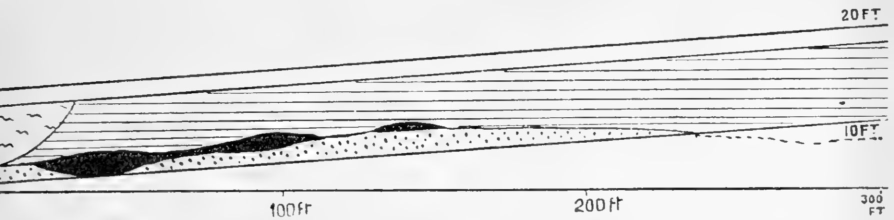
In the summer of 1911 I discovered numerous wind-worn stones in a gravel-pit near to Ramsdale, and situated at the side of the Old North Road 6 miles out of Nottingham. Samples of these were exhibited at the Geological Society's conversazione in 1912. During the next few months a trench for the water-main from the Derwent valley to Nottingham was opened along this road, and passed for a distance of over a mile through similar gravels, which in one place were at least 10 feet thick. Throughout this distance 'dreikanter' were common in the top 18 inches of soil and subsoil.

These wind-worn stones varied in size from small boulders 8 inches long to small pebbles. The majority were of quartzite and had assumed those forms usually associated with the term 'dreikanter'. Pebbles of less homogeneous constitution, such as grit, vein quartz, and various igneous rocks, were not as a rule facetted, but had that wavy, pitted, or undercut type of polished surface which is the characteristic effect of the sand-blast action of the wind and of insolation.

Further investigation shows that these wind-worn stones are not confined to the locality of Ramsdale, but are widely distributed over the whole district, on both Keuper and Bunter outcrops, from beyond Oxton in the north to Wilford Hill and Clifton in the south. No doubt future exploration will reveal their presence beyond these limits. They are most abundant in the soil of a sheet of gravelly drift which at Bestwood lies near the 400 ft. contour, but drops gradually towards the south and south-east. Similar gravels at Clifton and Wilford lie just above the 200 ft. contour. In any ploughed field situated on this sheet one may reasonably expect to collect a basketful of 'dreikanter' in the course of a short search.

The pebbles which have been worn are derived for the most part from the Bunter conglomerate, but the question naturally arises as to when they became wind-worn. In this connexion several periods suggest themselves, viz. Triassic times, late Pleistocene times, and quite recent times.

There seems to be no doubt that the prevailing climatic conditions in Britain during the Triassic period were such as to favour wind action, but of course locally these conditions were counteracted by others. Immediately around Nottingham, for example, the Bunter conglomerate exhibits all the characteristics of a rapidly formed deltaic deposit. It is not surprising, therefore, that though this formation has been subjected to assiduous search it has not yet yielded indubitable wind-worn stones. After deposition had ceased, however, its surface seems to have been vigorously swept by winds.



Section made from a portion of the sewer trench opened along Arnot Hill Road. Dotted area, Bunter Conglomerate. Black area, 'dreikanter'-bearing gravels. Lined area, plastic clay at the base of the Keuper Waterstones. Other areas, soil, subsoil, and alluvium.

This is indicated by observations made during the opening of a sewer trench along Hallam's Lane (now Arnot Hill Road), which leads from Arnold to Arnot Hill. My attention was called to the trench by Mr. R. E. Clarke, the surveyor for the Arnold District Council, who had been struck by the peculiar subsoils which were being entered.

The trench ran slightly obliquely to the strike of the Keuper, and for 70 yards its floor lay in the substance or on the surface of the Bunter, whilst its sides were made up of the bottom beds of the Keuper Waterstones (Pl. XVI, Fig. 1). The lowest of these was a plastic clay, 3 feet thick and of deep-red colour, in its unweathered portions. The surface of the Bunter conglomerate upon which it rested can only be described as wind-swept (Pl. XVI, Fig. 2), for many pebbles projected more or less completely above the surface, others rested loosely upon it, and all, in striking contrast to the typically water-worn form of those still embedded in the conglomerate, showed clear signs of wind erosion.

Throughout 40 yards of the section the loose pebbles were so numerous as to form lenticular accumulations of coarse gravel, which at one point swelled out to a thickness of 2½ feet. The only portions of the Bunter conglomerate which can be compared with these are the pockets of pebbles that occur here and there at the bottom of the channels, which give the rock its current-bedded appearance. One of these pockets cropped out at the wind-swept surface and produced a slight tump which was completely covered by the gravel. Even in these pebbly portions of the Bunter sand fills up the spaces between the pebbles, all of which are rounded. In the gravels, on the other hand, sandy matrix was absent and wind-worn and facetted stones were common (Pl. XVI, Fig. 3, *f*, *g*, *h*, *i*). Moreover, the line of separation between the gravel and the underlying Bunter was perfectly defined. There can be no doubt, therefore, that these 'dreikanter'-bearing gravels were laid down under very different conditions from those which accompanied the formation of Bunter deposits, and that they must have been formed after the latter had been subjected to the action of aerial denudation for some time.

Nor is there any question of the gravel having been transported into this position by currents of water, for the angles between the facets show no signs of having been blunted by rolling; on the other hand, they are buried under a very fine Keuper clay which could only have been laid down in tranquil water.

Confirmation of the occurrence of this episode in the history of the Trias of South Notts is forthcoming from the sand-pits at Dale Abbey, which lies just beyond the western county boundary. There the Bunter-like sandstone, which lies directly upon the Coal-measures, yields typical 'dreikanter'. For reasons which will be given in a later paper there is good ground for suspecting that these beds really belong to the same level as the 'dreikanter' gravels of Arnot Hill.

These Triassic wind-worn or wind-accumulated deposits are too discontinuous and limited in extent to account for even a fraction of the facetted and allied pebbles found in the drift. Whilst, therefore, a few may come from this source, the main mass of them must have been shaped by post-Glacial agencies.

To-day, when the wind is blowing over the Bunter outcrop the dust and sand raised from the landscape gives the effect of advancing cavalry. Drifts of sand 3 or 4 feet deep accumulate on the lee side of the hedges, and it is part of the ordinary duty of the farm labourer to redistribute the sand thus displaced by the wind. Such facts as these tempt one to believe that even up to the time when these lands were first enclosed for cultivation, 'dreikanter' were being carved. The fact that they seem to be confined to the top 18 inches of soil might be taken to point the same way. Nevertheless, certain phenomena associated with other gravels than those already mentioned seem to limit the main period of effective wind action to late Pleistocene times.

In the vale of the Trent near Nottingham there are two sets of gravels: the younger, which carpets the floor of the vale, everywhere underlies the alluvium, and occasionally rises up into low flat-topped

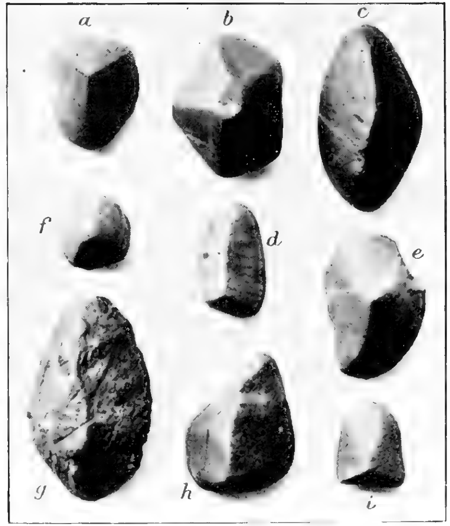
2

Wind-swept surface of Bunter.

1

Excavation through base of Keuper.

3



Facetted stones from Drift and Trias.

mounds a few feet above the flood-levels; the older, which occupies terraces about 20 feet higher and fringe the vale at Beeston, Gamston, and elsewhere. The ploughed fields and gravel-pits situated on these terraces all yield facetted and other types of wind-worn stones, but though the surface of the younger gravels have been carefully searched, not a single one has been found. It seems, therefore, that for a while the Trent, probably much swollen by the melting snows and ice of late Pleistocene times, cut out its trench-like valley with great rapidity, but that when it reached the level of the older gravel terraces it paused in the process. During this long pause climatic conditions were such as to favour effective wind-action. Subsequently the river deepened its vale a little more, but since that time this action has been reduced to a minimum.

EXPLANATION OF PLATE XVI.

FIG. 1. View of the Arnot Hill sewer trench. The boundary between the clay and the thickest part of the dreikanter-bearing gravels is indicated by the top of the workman's tool.

,, 2. Wind-swept surface of Bunter. Top right-hand portion shows the projecting and loose pebbles. On the left, and below, some clay is seen still adhering to the surface and surrounding the projecting pebbles.

,, 3. Facetted stones. Those marked *a*, *b*, *c*, *d*, *e* were collected from various points on the sheet of gravelly drift. Those marked *f*, *g*, *h*, *i* were collected from the Triassic 'dreikanter' gravel of Arnot Hill.

IV.—NOTE ON THE SOURCE OF THE PEBBLES OF THE BUNTER PEBBLE-BEDS OF THE ENGLISH MIDLANDS.

By C. A. MATLEY, D.Sc., F.G.S.

THE subject of the derivation of the materials which form the Bunter Pebble-beds has given rise to wide differences of opinion and to a voluminous literature. These it is not my intention to recapitulate, as an excellent summary of the subject will be found in Mr. O. H. Shrubsole's paper of 1903.[1] Mr. Shrubsole then gathered together the known evidence, added some new facts of his own, and came to the conclusion that the Midland Bunter pebbles were brought from a southerly direction. This opinion may be said to have held the field until recently, when the question was again taken up by Mr. Jukes-Browne in the third edition of *The Building of the British Isles* (1911). After reviewing the whole evidence and taking into consideration the results of an investigation by Mr. E. C. Martin, which tended to show that the direction of transportation in Somersetshire in Bunter times was towards the south, Mr. Jukes-Browne abandoned the view he had taken in the second edition (1892) of that work, and now, adopting in the main the conclusions of Professor Bonney, considers that the bulk of the pebbles of the

[1] "On the Probable Source of some of the Pebbles of the Triassic Pebble-beds of South Devon and of the Midland Counties": Q.J.G.S., vol. lix, pp. 311–31, 1903.

Midland Bunter came from the north-west, though he agrees that the fossiliferous quartzite pebbles could not have come from that direction, and he suggests for these a south-easterly derivation (Suffolk).

The question cannot, however, be considered as finally settled by this pronouncement, and I am tempted to re-open it in the hope of stimulating further investigation. I also urge a fuller consideration of Mr. Shrubsole's arguments, which do not appear to have been sufficiently appreciated.

Although hitherto refraining from the discussion of this problem[1] I have for over thirty years taken an interest in it. While yet a schoolboy I followed the example of P. B. Brodie, W. Jerome Harrison, and others by collecting the fossiliferous quartzite pebbles of Bunter origin found in the Drift of the Birmingham district. At a later date, when engaged in mapping the Keuper Marls of Warwickshire, I turned my attention again to the associated Drift, from which I got together a further collection of the fossiliferous, as well as of non-fossiliferous pebbles. It was not till last winter, however, that I was able to take up their examination in detail, and it so happened that I had not proceeded far with the work when I had to leave it owing to taking up an appointment in India at very short notice. As I shall not be able to resume this work for at least two years, it seems convenient to give a short account of the evidence on which I came years ago to conclusions almost completely in accord with those of Mr. Shrubsole, and which I have as yet seen no good ground for modifying.

A large proportion of the pebbles which occur so abundantly in the Drift of the Birmingham district have unquestionably been derived from Bunter beds, and though in theory it appears unsafe to frame arguments as to the Bunter deposits from material found in the Drift, the worker who is acquainted with both sets of deposits has usually no hesitation in deciding that certain pebbles in the Drift are of Triassic origin. I should, of course, have preferred to deal with the Bunter pebbles at first hand, but my geological work happened to lie on Keuper Marls, and the investigation of the Bunter material found in the Drift of that area was only pursued as a side issue to my study of the Drift.

Fossiliferous quartzite pebbles are distinctly rare; as Mr. W. J. Harrison has remarked, probably not more than one pebble in a thousand is fossiliferous. Those containing worm-burrows are most abundant, and my collection contains about fifty such pebbles (of which two came direct from the Bunter Conglomerate), though I could have obtained probably twice that number had I collected every specimen I found. These burrows are all straight sub-cylindrical tubes which can be grouped roughly into about four types, according to diameter and amount of corrugation. The differences may not, however, be specific, but be dependent merely upon the amount of

[1] Except in the discussion on Dr. A. E. Salter's paper "On the occurrence of Pebbles of Schorl-rock from the South-west of England in the Drift Deposits of Southern and Eastern England": Q.J.G.S., vol. lv, pp. 220–3, 1899.

growth of the individual worms. No other organisms occur in these pebbles, the age of which is uncertain, but one of the types is certainly the *Tigillites dufresnoyi*, Rou. (*Trachyderma serrata*, Salt.) of the Grès de May.

Next in abundance come the Brachiopoda, preserved in about seventy pebbles. A preliminary examination, which was all I was able to give them, showed that the species agreed very closely with those found in the Budleigh Salterton pebbles and that they yielded the three faunas already known to occur both in the Devonshire beds and in other collections of Bunter pebbles from the Midlands. The three faunas are those of (1) the Grès Armoricain, (2) the Grès de May, and (3) the Devonian, and the typical species are distinctly southern forms that are not found in situ nearer than the North of France and the South of England. The Grès de May is the most abundantly represented of the three, *Orthis* (*Dalmanella*) *budleighensis*, Dav., being by far the commonest species, as over thirty pebbles contain this form and in a number of them the specimens occur gregariously. Other *Orthides* in the collection probably also belong to this formation, as, for example, *Orthis* cf. *berthoisi*, var. *erratica* and some other species, not yet determined, which seem to be of approximately Bala age.

The Grès Armoricain is well represented by *Lingula lesueuri*, Rou. (about ten examples), by fewer examples of *Lingula hawkei*, and by one specimen which is probably *Dinobolus brimonti*. Some small Lingulidæ have also been obtained, which may be immature examples of one or both of the above-mentioned species.

The Devonian forms seem to be rarer, but my collection contains several specimens of Spirifer, of which some seem to be identical with the form recorded by Davidson as *Spirifer verneuili*, and it is associated with *Camarotœchia* cf. *elliptica*, Schnur. The other Spirifers have not yet been fully studied.

In addition to the above there are a number of Lamellibranchs, a few pygidia and other fragments of Trilobites, and occasional Echinoderm-remains, etc. Though they have not yet been examined, they will no doubt confirm and extend the results yielded by the Brachiopods. In order that they may be available for future research I have handed over the whole collection to the Geological Survey Museum, Jermyn Street.

The palæontological evidence must, I think, be accepted as conclusive that the quartzite and quartzose-sandstone pebbles containing these fossils came from some southerly point, though there is room for speculation as to whether they were derived from the area in which the fossils are to be found at the present day, viz. Normandy and the region adjacent, or from some tract in the South or South-East of England now buried beneath Mesozoic or Cainozoic deposits. This being so, why should not the great bulk of the associated non-fossiliferous pebbles, which cannot be distinguished externally by shape, size, colour, or texture from the fossiliferous ones, have come from the same area? I have seen something of the Old Red Conglomerates of Scotland, and recognize the striking resemblance that their contained quartzite pebbles bear (except as regards fossils) to those of the Midland Bunter; but the fact that the Midland Bunter pebbles decrease rapidly in size and number as the beds are followed to the north-west and north-east offers so grave an objection to the theory of a Scottish origin, and on the other hand the palæontological and lithological evidence so strongly supports the view of a southern source for these quartzites, that it seems to me the former theory should definitely give place to the latter.

There is also another line of lithological evidence which supports the 'southern' theory. Occurring as a characteristic though minor element in the Bunter Conglomerate and as derived pebbles in the Drift are some pebbles of schorl-bearing rocks. The majority are tourmalinized quartzites and grits, some are of schorlaceous breccia, while a few are of schorlaceous granite, the latter being ordinarily too decomposed to be of petrographical value. The presence of such rocks has long been known; Mr. S. G. Perceval collected them from the Drift and Mr. T. H. Waller described them microscopically many years ago, while Professor Bonney did so from the Bunter later; but their importance as bearing on the general problem of the origin of the Bunter pebble-bed does not seem to have been fully recognized. Although tourmaline-bearing rocks are known in other parts of the British Isles they occur most characteristically and in greatest force in Devon and Cornwall, and the types found as pebbles can be well matched there. To test this fact I selected two pebbles from the Drift near Birmingham, one being a schorl-breccia in which Mr. G. Barrow thought he recognized a typical fragment of Cornish 'Killas' and the other a pebble of exceptionally fresh schorlaceous granite. They are now in the Jermyn Street Collection, and Dr. H. H. Thomas has been good enough to allow me to make use of the following notes of his microscopical examination of thin slices made from them:—

E. 9553. South of California, near Harborne. Breccia of pale fine-grained rock in dark-grey to black matrix. Schorlaceous breccia. The fragments are mainly of fine-grained quartzose sediments and occasionally of felsite with fluxion-structure. The matrix consists of a mass of the finest acicular tourmaline of blue-green colour. The tourmalinization of the rock as a whole appears to have been accomplished after the brecciation, for the process has affected the larger fragments wherever they contained any aluminous material.

E. 9554. From a pebble-heap near Kent Cottages, Sheldon, near Birmingham. Schorlaceous granite. The rock is composed of orthoclase, quartz, and tourmaline. The slightly decomposed orthoclase and quartz are intergrown occasionally with an approach to micrographic structure. The tourmaline of the larger crystals is brown, but these crystals invariably have an outer blue layer. The smaller crystals and needles of this mineral are of a blue colour as in luxullianite. The tourmaline occurs alike in the quartz and in the orthoclase.

Dr. Thomas adds that "It is hard to assign any other source to these pebbles than the West of England, for in that region alone can the types be matched with any degree of closeness".

From the above evidence the principal source of the Midland Bunter pebbles seems to me to lie in an area embracing the South-West of England and the North-West corner of France. Until borings yield some positive evidence (which, so far as I know, they have not yet done) that the buried Palæozoic rocks of the South-East and East of England contain the right rock-types and the right fossils I would not give those buried areas special consideration.[1] If the objection be made that the geographical conditions of Bunter time were such that a rock barrier prevented the flow of these materials from the south-west into the Midlands, as indicated in Mr. Jukes-Browne's map (op. cit., fig. 34), then the evidence for the complete barrier ought to be carefully collected and the impossibility of a connexion be clearly proved. I suggest that one of the tributary streams that carried the Bunter gravels may have followed the line of the present Bristol Channel, a course which would provide a likely source of the Carboniferous Limestone (often silicified), Chert, Llandovery Sandstones,[2] etc., as well as of the schorl-rocks, which occur in the Midland Bunter.

There must have been some local contributions to the Midland Triassic pebbles; and local quartzites like those of the Lickey and Hartshill and some of the rock-fragments in the Permian breccia probably played some part, though a minor part, in contributing to the mass of these materials.[3]

In spite of much excellent work that has already been done, much remains to be accomplished. For instance, among the rarer pebbles to be met with in the Bunter Conglomerate are various examples of hard rocks, apparently of great antiquity, which it has not been my experience to meet in situ in the field or to see in museum collections of British rocks. A careful collection of these rarer and special types, a record of the distribution of each type, and a correlation with similar rocks exposed at the present day would probably lead up to valuable results. In seeking for correlations the rocks of Brittany should not be overlooked.

I regret to have had to present this paper while so much of my collected material remains unstudied, but the circumstances are exceptional, and, as already stated, I wish to stimulate further research into this important and interesting subject.

I have had to write the above without access to books of reference, maps, or specimens, so that apart from some notes I have had to rely on memory for many statements.

[1] It is true that *Spirifer verneuili* was found in the Tottenham Court Road boring, but it is a widely distributed Devonian fossil, and it occurred there in a matrix altogether different from the Bunter pebble type.

[2] I have not seen the specimens, but I would be inclined to eliminate from the published lists of fossils found in Drift pebbles and ascribed to the Bunter those that indicate a Llandovery age. For instance, *Stricklandinia lirata* in W. J. Harrison's list is found in the Rubery Sandstone of the Lickey Hills. This sandstone is made up of the waste of the Lickey Quartzite, on which it rests unconformably, and it sometimes simulates in texture and appearance the older rock. Specimens from this source may have come direct into the Drift without ever having become Bunter pebbles, and in either case they are of local origin.

[3] The less-rounded quartzite pebbles of the Lower Keuper basement-beds of the Midlands suggest a derivation from local quartzites. The materials of these beds, as Mr. Harrison remarked in 1882, deserve careful and detailed study.

V.—The Foraminifera of the Speeton Clay of Yorkshire.

By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S.

(PLATES XVIII AND XIX.)[1]

Introduction.

THE Speeton Clay of Yorkshire is of considerable interest, as it is the chief marine representative of the Lower Cretaceous formations in England. It has been the subject of important papers by Professor J. W. Judd, F.R.S.,[2] and Mr. G. W. Lamplugh, F.R.S.,[3] while the palæontology of the Cephalopoda and Lamellibranchiata has been respectively worked out by Professor A. P. Pavlow[4] and Mr. H. Woods.[5] Mr. C. G. Danford[6] has also contributed to our knowledge of the beds. The Microzoa, however, have never been examined, and the present paper gives the results of an investigation of the Foraminifera of the deposit.

I am indebted to Mr. Lamplugh for the suggestion that I should undertake the work, and to him and Mr. C. G. Danford for the specimens of clay which have been examined. The condition of the cliffs at Speeton is such that many horizons of the clay are only rarely exposed, as, for example, after storms, so that it is very difficult to obtain specimens of these subdivisions. Mr. Danford has known the Speeton cliffs for many years and has that special knowledge of the various beds without which it would be impossible to obtain specimens of any value for zonal work. My thanks are also due to Mr. F. Chapman for his advice on many knotty points and to Dr. F. L. Kitchin and Mr. C. D. Sherborn for valuable suggestions.

Literature.—There is practically no literature relating to the Foraminifera of the Speeton Clay of Yorkshire. Mr. Lamplugh, in his earlier paper, refers to the presence of large and well-preserved Foraminifera in the *Echinospatangus* bed (C_3), and notes that they are "found cemented together in small hard pellets not often larger than shot-corns" (op. cit., p. 596). In his lists of fossils (pp. 599, 602) he records the presence of Foraminifera in D_1, C_{11-1}, and B.

The late Rupert Jones inserts *Pulvinulina caracolla* (Roemer) from the Speeton Clay in his *Catalogue of the Fossil Foraminifera in the*

[1] [Plates XVIII and XIX have been unavoidably delayed and will appear with the subsequent portion of this paper.—Ed.]

[2] J. W. Judd, "On the Speeton Clay": Q.J.G.S., vol. xxiv, pp. 218–50, 1868. "Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire, with Notes on their Relations to the Beds of the same age throughout Northern Europe": Q.J.G.S., vol. xxiv, pp. 326–48, 1868.

[3] G. W. Lamplugh, "On the Subdivisions of the Speeton Clay": Q.J.G.S., vol. xlv, pp. 575–618, 1889. "On the Speeton Series in Yorkshire and Lincolnshire": Q.J.G.S., vol. lii, pp. 179–220, 1896.

[4] In A. Pavlow & G. W. Lamplugh, "Les Argiles de Speeton et leur Equivalents": Bull. Soc. Imp. des Naturalistes de Moscou, N.S., vol. v, pp. 181–276, 455–570, 1891–2.

[5] H. Woods, A Monograph of the Cretaceous Lamellibranchiata of England (Pal. Soc.), 1899–1913.

[6] C. G. Danford, "Notes on the Belemnites of the Speeton Clay": Trans. Hull Geol. Soc., vol. vi, pt. iii, pp. 1–18 (plates), 1905 [1906]. Also "Notes on the Speeton Ammonites": Proc. Yorks Geol. Soc., vol. xvi, pt. i, pp. 101–14 (plates), 1906 [1907]; and other papers.

Collection of the British Museum (Natural History), 1882, p. 9. Specimens of this species, named by Rupert Jones, are in the British Museum and in the Museum of Practical Geology.

The Foraminifera of the Red Chalk, which lies above the Speeton Clay, have been described by Messrs. H. W. Burrows, C. D. Sherborn, and G. Bailey in "The Foraminifera of the Red Chalk of Yorkshire, Norfolk, and Lincolnshire", Journ. Roy. Micr. Soc., 1890, pp. 549–66, pls. viii–xi.

Foraminifera from rocks of approximately the same age as the Speeton Clay have been described by (1) A. E. Reuss in his paper "Die Foraminiferen der norddeutschen Hils und Gault", Sitzungsber. k. Akad. Wiss. Wien, vol. xlvi, Abth. i, pp. 5–100, pls. i–xiii, 1862 (1863). (2) J. Cornuel, "Description de nouveaux fossiles microscopiques du terrain crétacé inférieur du département de la Haute-Marne," Mém. Soc. géol. France, sér. II, vol. iii, pp. 241–63, pls. iii, iv, 1848. (3) F. Chapman, "The Bargate Beds of Surrey and their Microscopic Contents," Q.J.G.S., vol. l, pp. 677–730, pls. xxxiii, xxxiv, 1894. (4) F. Chapman, "The Foraminifera of the Gault of Folkestone," pts. i–x, in Journ. Roy. Micr. Soc., 1891–8. (5) G. Berthelin, "Mémoire sur les Foraminiféres fossils de l'Etage Albien de Montcley (Doubs)," Mém. Soc. géol. France, sér. III, vol. i, No. 5, pp. 1–84, pls. xxiv–vii, 1880.

Treatment of Material.—The specimens examined were small, usually from 1 to 2 cubic inches, so that the list of Foraminifera cannot be regarded as exhaustive, but it is clear that there are not more than four horizons in the zones C, D, E, and F (see pp. 218, 219) which are likely to repay a further search.

The dry clay was broken into small pieces about the size of a pea, and these fragments were heated gently over a Bunsen burner and dropped whilst hot into cold water. After standing for a short time the sediment was washed free from fine mud and the residue dried and passed through a sieve. The sediment was then passed through, first, coarse, and then through fine muslin, and the different residues were examined under the microscope for Foraminifera. The great majority of the forms were obtained from that part which had passed through coarse muslin but was stopped by fine muslin. One or two specimens of hard shale refused to break up under this treatment, and these were examined in minute fragments under the microscope.

The results of the investigation are somewhat disappointing. The specimens of Speeton Clay examined, except from a few horizons, are almost without Microzoa, and those found have, as a rule, few special characteristics.

Stratigraphical Distribution.—The beds were divided by Mr. Lamplugh[1] into the following main divisions in downward succession :—

A. Marls with *Belemnites minimus*, List., and allies.
B. Zone of *B. semicanaliculatus* (?) and allies.
C. Zone of *B. jaculum*, Phil., and varieties.
D. Zone of *B. lateralis*, Phil., and varieties.
E. Coprolitic seam.
F. Bituminous shales with varieties of *B. Owenii*, Pratt.

[1] Q.J.G.S., vol. xlv, p. 581, 1889.

Professor A. P. Pavlow[1] correlates these divisions with those of the Continent as follows:—

[Aptien] = B.
Barrémien = C_1–C_1 [an evident misprint for C_1–C_7].
Hauterivien = C_8–C_{11}.
Valengien = D_1, lower part, D_3.
Upper Tithonian = D_4–D_8.

No Foraminifera whatever were found in divisions F and E (Upper Kimeridge[2]). I have not any specimens from A, and in the case of B only from the basal bed. Theoretically D should have proved the most interesting, as doubts have been expressed whether this division should be regarded as Jurassic or Cretaceous, but Foraminifera are comparatively rare in D. However, some evidence has been obtained and will be referred to later. Of the eight subdivisions of D, Foraminifera have been found in D_2, D_3, and D_6 only.

In C_1, which is certainly of Lower Cretaceous age, Foraminifera were found in C_1, C_2, C_3, C_7, C_9, and C_{10} of the eleven subdivisions, but I have no material from C_4, C_5, and C_6. In B the base was alone examined, and proved to be one of the best horizons for Microzoa. I have not found specimens from any bed higher than the base of B.

The information obtained is summarized in the following notes on the divisions examined, commencing with the lowest bed.

F. Upper Kimeridge. The extreme top of F is a black shale which is most difficult to break up for the purpose of separating any Microzoa that may be present. A few minute white spherical bodies may be the initial cells of Foraminifera.

D_8. The base of D_8 contains selenite, an indication that any calcareous Microzoa have been destroyed. The horizon is interesting mineralogically as it contains grains of garnet, kyanite, and other heavy minerals, together with quartz-sand and a few grains of phosphate.

D_7 (the blue band). Only traces of shells remain, the rest have undergone decomposition.

D_6 (lower part). Crystals of selenite indicate destruction of calcareous fossils.

D (middle part). A few Foraminifera and Ostracoda were found. The former comprise *Nodosaria* sp., *Marginulina jonesi*, Reuss, *Rhabdogonium insigne*, Reuss, *Vaginulina* sp. (fragment), *Cristellaria acutauricularis* (Fichtel & Moll), *C. cultrata* (Montfort), *C. gaultina*, Berthelin, *C. rotulata* (Lamarck), *Pulvinulina caracolla* (Roemer), glauconite casts of Cristellarians, and an arenaceous form. There are a few grains of a transparent cubic mineral which is probably garnet, and grains of coloured quartz.

[1] "On the Classification of the Strata between the Kimeridgian and Aptian": Q.J.G.S., vol. lii, pp. 542–55, pl. xxvii, 1896.

[2] A recent paper by Dr. Hans Salfeld (Q.J.G.S., vol. lxix, pp. 423–32, pls. xli, xlii, 1913) indicates that Portlandian beds may be present in this division of the Speeton Clay.

D_6 (upper part). Fragments of shells and crystals of selenite.

D_5. No Foraminifera.

D_4. Small rod-like bodies, apparently glauconite casts. Quartz grains.

D_3. Small rod-like bodies as in D_4 and occasionally a minute nodule of pyrites. Foraminifera are rare and comprise an arenaceous form and *Cristellaria rotulata* (Lamarck).

D_2 (base). Some glauconite grains. A fair number of Foraminifera, but the specimens are usually imperfect. Arenaceous forms are more frequent in this than in any other zone examined. For the most part they are very fragile and fall to pieces readily, and it is probably this fragile character that causes them to be relatively rare in the Speeton Clay.

The following are the Foraminifera found and determined: *Bulimina* sp., *Cristellaria cultrata*? (Montfort), *Pulvinulina caracolla* (Roemer).

A number of small, nearly circular grains resemble arenaceous Foraminifera, but examination in oil of cloves shows that there is a radial crystalline structure and the grains appear to be concretions. Mr. H. H. Thomas has kindly examined them for me and finds that they are composed of gypsum.

D_2 (top). Some glauconite grains and a few poor specimens of Foraminifera.

C_{11}. Abundant grains of glauconite, some, at least, being casts of Foraminifera.

C_{10}. Foraminifera moderately abundant. The species are *Lagena globosa* (Montagu), *L. apiculata*, Reuss, *Nodosaria* (*Glandulina*) *lævigata*, var. *strobilus*, Reuss, *Cristellaria gibba*, d'Orb. There are also present Ostracods, and grains of a red mineral which is probably garnet.

C_9. Foraminifera not numerous. They are *Lagena apiculata* (?), Reuss (broken), and *Cristellaria rotulata* (Lamarck). In addition there are fragments which appear to be *Inoceramus* prisms. As *Inoceramus venustulus*, Bean, is abundant at this horizon, it is very probable that the fragments are derived from this mollusc.

C_8 (?). There is some doubt as to the horizon from which the specimen was collected. In any case no recognizable Foraminifera were obtained.

C_7. A fair number of specimens of *Pulvinulina caracolla* (Roemer) were obtained, all broken.

C_3 (upper part)? I have not been able to obtain specimens of the strata between C_7 and the upper part of C_3, and the specimen from the latter horizon is not free from doubt as regards its exact position. It contains grains of glauconite and a considerable number of Foraminifera. These are chiefly specimens of *Pulvinulina caracolla* (Roemer), and are usually broken and filled with glauconite. *Cristellaria gibba*, d'Orb., *C. rotulata* (Lamarck), and *Pulvinulina lamplughi*, sp. nov., also occur, and these latter forms are not broken.

C_2 (upper part)? Here, again, there is some doubt as to the exact horizon of the material, and it is particularly unfortunate, since this bed is one of the most prolific in Foraminifera. Specimens are very numerous, but the great majority belong to a single species, *Pulvinulina caracolla* (Roemer). Although the specimens are often broken, they are on the whole better preserved than in C_3 (?). The species are: *Reophax scorpiurus*, Montfort, *Ammodiscus gordialis* (Jones & Parker), *Lagena globosa* (Montagu), *L. apiculata*, Reuss, *L. apiculata*, var. *danfordi*, var. nov., *L. lævis* (Montagu), *Nodosaria* (*Dentalina*) *fontanessi*, Berthelin, *N.* (*D.*) *lorneiana*, d'Orb., *N.* (*D.*) *communis*, d'Orb., *N.* (*D.*) *roemeri*, Neugeboren, *Frondicularia gaultina* (?), Reuss, *Marginulina linearis*, Reuss, *M. jonesi*, Reuss, *M. debilis*, Berthelin, *Cristellaria gibba*, d'Orb., *C. chapmani*, sp. nov., *C. crepidula* (Fichtel & Moll), *C. turgidula*, Reuss, *C. rotulata* (Lamarck), *Polymorphina fusiformis*, Roemer, *P. problema*, d'Orb., *Pulvinulina repanda* (Fichtel & Moll), *P. caracolla* (Roemer), and *P. lamplughi*, sp. nov.

A minute *Dentalium*, minute spines of Echinoids, and a few Ostracods were also found. The material contains a little glauconite. All the particles, except the finest, are well rounded, but the Foraminifera, other than *P. caracolla*, are well preserved.

C_1. Many grains of glauconite, some of them obviously internal casts of Foraminifera. A moderate number of Foraminifera were found, almost all of them Cristellarians. The species are: *Lagena globosa* (Montagu), *L. apiculata*, Reuss, *Cristellaria acutauricularis* (Fichtel & Moll), *C. turgidula*, Reuss, and *C. rotulata* (Lamarck).

B (base *a*). Three specimens of the basement beds of B were examined, called *a*, *b*, and *c*, of which *a* is the lowest. This last material yielded a few decomposed Foraminifera, one being a rotaline form. It is probable that fossils were originally present in fair number, but they have been destroyed by the alteration of the calcite into gypsum. *Inoceramus* prisms were noted.

B (base *b*). Abundant glauconite grains, some of which are obviously the internal casts of Foraminifera. In addition the following shells were found: *Nodosaria hispida*, d'Orb., *Marginulina jonesi*, Reuss, *Cristellaria cephalotes*, Reuss, *C. rotulata* (Lamarck), *Pulvinulina caracolla* (Roemer).

B (base *c*). This horizon is perhaps the richest in Foraminifera of all those examined. In many of the specimens the shells are filled with glauconite and have been partly worn away. Under the microscope the material seems to be made up of small 'pebbles' of shale, and much of it may be derived from an older deposit. The majority of the individuals are young fry. The species found are: *Haplophragmium latidorsatum* (Bornemann), *Textularia agglutinans*, d'Orb., *Bigenerina nodosaria*, d'Orb., *Gaudryina filiformis*, Berthelin, *Lagena apiculata*, Reuss, *L. lævis* (Montagu), *Nodosaria calomorpha*, Reuss, *N.* (*Dentalium*) *siliqua* (?), Reuss, *N.* (*D.*) *legumen*, Reuss, *Marginulina glabra*, d'Orb., *Cristellaria gracillissima*, Reuss, *C. acutauricularis* (Fichtel & Moll), *C. scitula*, Berthelin, *C. chapmani*, sp. nov., *C. crepidula* (Fichtel & Moll), *C. gaultina*, Berthelin, *C. sternalis*, Berthelin, *C. orbiculata* (Roemer), *C. rotulata* (Lamarck), *Polymorphina fusiformis*, Roemer, *Pulvinulina repanda* (Fichtel and Moll), *P. caracolla* (Roemer), *P. lamplughi*, sp. nov.

Family LITUOLIDÆ.

Sub-family LITUOLINÆ.

Reophax, Montfort.

Reophax scorpiurus, Montfort. (Pl. XVIII, Fig. 1.)

Reophax scorpiurus, Montfort, 1808: Conchyl. Système, vol. i, p. 330, 83e genre.
Nodosaria agglutinans, Terquem, 1870: Mém. Acad. Imp. Metz, 1869–70, p. 252, pl. xxix, fig. 18.
Reophax helvetica, Haeusler, 1883: Q.J.G.S., vol. xxxix, p. 27, pl. ii, figs. 8–10.

Remarks.—Two specimens, differing considerably in size, seem to belong to this species, although the larger one resembles somewhat *R. pilulifera*, Brady (Chall. Rep., p. 292, pl. xxx, figs. 18–20). *R. scorpiurus* is known from the Swiss Jurassic (Haeusler), the Oolite of Fontoy, Moselle (Terquem), and the post-Tertiary of Norway (Crosskey & Robertson). Chapman records it from the Folkestone Gault. At present it is a very common cosmopolitan species at from 3 to 3,960 fathoms (Brady). *R. pilulifera*, however, to which the larger specimen has affinities, is confined to deep water, having been found from 800 to 2,435 fathoms (Brady, Chall. Rep.).
Horizon.—Found in Upper C_2. Two specimens.

Haplophragmium, Reuss.

Haplophragmium latidorsatum (Bornemann). (Pl. XVIII, Fig. 3.)

Nonionina latidorsata, Bornemann, 1855: Zeitschr. d. deutsch. geol. Gesell., vol. vii, p. 339, pl. xvi, figs. 4*a*, *b*.
Haplophragmium crassum, Reuss, 1867: Sitzungsb. d. k. Ak. Wiss. Wien, vol. lv, p. 46, pl. i, figs. 1, 2.
H. rotundidorsatum, Hantken, 1875: Mittheil. Jahrb. d. k. ung. geol. Anstalt, vol. iv, p. 12, pl. i, fig. 2.

Remarks.—The species has been recorded by Bornemann from the Septaria-clay of Hermsdorf, near Berlin, by Reuss, from the Salt-clay of Wielizka in Galicia, and by Hantken from the Clavulina-Szaboi Beds of Hungary, all of which are of Middle Tertiary age. Chapman records it from the Folkestone Gault, and it is at present a deep-sea form according to Brady.
Horizon.—One specimen from B base *c* (unfortunately lost after drawing).

Sub-family TROCHAMMININÆ.

Ammodiscus, Reuss.

Ammodiscus gordialis (Jones & Parker). (Pl. XVIII, Fig. 5.)

Trochammina gordialis, Brady, 1876: Monogr. Carb. and Perm. Foram., p. 77, pl. iii, figs. 1–3.

Remarks.—The species is known from the Carboniferous rocks of Great Britain and Belgium, and from the Permian of Northern England, and it is still living. Brady (Chall. Rep.) records its presence in seas varying in depth from 50 to over 2,000 fathoms.
Horizon.—Found in Upper C_2. One specimen.

Family TEXTULARIIDÆ.

Sub-family TEXTULARIINÆ.

Textularia, Defrance.

Textularia agglutinans, d'Orb.

Textularia agglutinans, d'Orbigny, 1839: Foram. Cuba, p. 136, pl. i, figs. 17, 18, 32–4.

Remarks.—The species is recorded from the Folkestone Gault (Chapman), the Red Chalk of Speeton (Burrows, Sherborn, & Bailey), and is still living at widely different depths (Brady).

Horizon.—A simple specimen was found in B base *c* and lost.

Bigenerina, d'Orbigny.

Bigenerina nodosaria, ? d'Orb. (Pl. XVIII, Fig. 2.)

Bigenerina nodosaria, d'Orbigny, 1827: Ann. Sci. Nat., vol. vii, p. 261, No. 1, pl. xi, figs. 9–12; Modèle No. 57.
B. nodosaria, Terrigi, 1880: Atti dell'Accad. Pontif., ann. xxxiii, p. 192, pl. ii, fig. 28.
B. nodosaria, Brady, 1884: Chall. Rep., vol. ix, p. 369, pl. xliv, figs. 14–18.

Remarks.—The single specimen found has only two cells in the uniserial portion of the shell, and the arrangement of the initial cells is not clear, so that there is some doubt as to the determination. The species has been recorded in the Miocene of the Viennese Basin and of Malta (d'Orbigny, Parker & Jones), and in the later Tertiaries of North Germany (Roemer), Italy (Costa, Terrigi), and Spain (Parker & Jones). Brady states that it is common in the North Atlantic and is also found in the North Pacific at depths varying from 7 to 1,630 fathoms.

Horizon.—Found in B base *c*. One specimen.

Gaudryina d'Orbigny.

Gaudryina filiformis, Berthelin. (Pl. XVIII, Fig. 4.)

Gaudryina filiformis, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 25, pl. i, fig. 8.
G. filiformis, Wright, 1882: Proc. Belfast Nat. Field Club, 1880–1, App., p. 180, pl. viii, figs. 3, 3*a*, *b*.
G. filiformis, Chapman, 1892: Journ. Roy. Micr. Soc., p. 752, pl. xi, fig. 7.

Remarks.—The triserial commencement of this form is very small and difficult to make out. The species is known from the Gault of France (Berthelin) and of Folkestone (Chapman). It is still living, and has been recorded from shallow water by Wright, Balkwill, and Robertson, and by the *Challenger* Expedition from four stations at depths varying from 390 to 620 fathoms.

Horizon.—Found in B base *c*. Two specimens.

Sub-family BULIMINÆ.

Bulimina, d'Orbigny.

Bulimina sp.

A broken and coarsely arenaceous specimen of this genus was found in D_2 (base).

(*To be continued.*)

NOTICES OF MEMOIRS.

A New Classification of Ore-deposits. By Dr. F. H. Hatch.

In his presidential address to the Institution of Mining and Metallurgy,[1] Dr. F. H. Hatch gave the following outline of a new classification of ore-deposits:—

Modern views on ore-genesis may be reduced to two principal lines of inquiry, the one dealing with the agent or vehicle, by which the metals have been collected, conveyed to, and deposited in the places where they are now found, and the other with the nature of the concentrates formed in the course of these processes.

Considering the latter first, ore-deposits are found to be either—

1. Igneous differentiates.
2. Cavity-fillings.
3. Metasomatic replacements.
4. Stratified or sedimentary deposits.
5. Residual deposits.

Of these, the sedimentary deposits comprise marine, lacustrine, and fluviatile accumulations, including placers.

Coming now to the agent or vehicle of ore-concentration, these are found to be—

(*a*) Molten magmas.
(*b*) Gases and vapours above their critical temperatures.
(*c*) Deep-seated waters, whether of magmatic or of meteoric origin.
(*d*) Vadose waters.
(*e*) Chemical and bacterial agents in lakes and seas.
(*f*) Mechanical agents, such as moving water and wind.

It is possible, by combining the facts elicited by these two lines of inquiry, to formulate a genetic scheme of classification. For example, cavity-filling may be due to igneous injection, to gases and vapours above their critical temperatures, to deep-seated waters, or to vadose waters; again, metasomatic replacement may be brought about by gases and vapours, by deep-seated waters, or by vadose waters. By arranging these two series of relationships in vertical and horizontal columns respectively, all the various types of ore-deposits are obtained at their intersections; and in this way the classification shown in the accompanying Table (pp. 224–5) is obtained.

"Considering the world-wide interest of England in the mining of precious metals throughout the world, it seems rather singular that so little attention is being given to ore-deposits by the geologists and engineers of that country. It is true that there are notable exceptions to this, but with English mining engineers working in the most remote parts of the world it seems as if their contributions to the science of ore-deposits is disproportionately small."[2]

[1] Delivered at the annual meeting of the Institution held at Burlington House on March 26.

[2] Lindgren, "Tendencies in the Study of Ore-deposits": Econ. Geol., vol. ii, p. 745, 1907.

CLASSIFICATION OF ORE-DEPOSITS.

Nature of Deposit.	Vehicle or Agent		
	(*a*) **Molten Magmas.**	(*b*) **Gases and Vapours** above their critical temperatures.	(*c*) **Deep-seated Waters,** whether of magmatic or meteoric origin.
1. Igneous Differentiates.	Certain massive iron and nickel ores associated with basic igneous intrusions (e.g. those of Sudbury in Ontario).		
2. Cavity-fillings.	Injected tin-ores (e.g. tin-pegmatites and tin-elvans on the margin of granite intrusions).	Pneumatolytic cavity-fillings (e.g. tin quartz veins).	Hydato-genetic cavity-fillings (many fissure veins).
3. Metasomatic Replacements.		Pneumatolytic replacements (e.g. tin-greisens and many contact-deposits).	Hydato-genetic replacements (many veins and massive deposits, also the Rand Banket).
4. Stratified Deposits.			Possibly some sedimentary deposits in which the cementing materials are ores of the metals.
5. Residual Deposits.			

BY DR. F. H. HATCH, PRES. INST. MIN. & MET., ETC.

OF ORE-DEPOSITION.

(*d*) **Vadose Waters.**	(*e*) **Mechanical Agents** such as moving water and wind.	(*f*) **Chemical and Bacterial Agents** in seas, lakes, and swamps.
1.		
2. Superficial fracture-fillings, such as gash-veins in limestones and cavity-fillings (e.g. the hæmatite ores of Cumberland).		
3. Some lead and zinc ores in limestones. Iron-ores replacing limestones (e.g. Cleveland). Some lateritic iron and manganese deposits. Secondary enrichments of copper ores.		
4. Some lead and copper ores interstitial in sandstones and shales.	Mechanical concentrates in bedded deposits (e.g. gold and platinum placers, stream-tin, iron-sands, detrital laterites, and other metalliferous gravels and sands).	Chemical and bacterial sediments (e.g. lake- and bog-iron ores, clay-ironstone and other sedimentary siderites, bog-manganese-ore and other sedimentary manganese ores).
5. Mantle-deposits, e.g. pisolitic and nodular ores of iron (e.g. the Bilbao and Appalachian hæmatites and limonites), of manganese (psilomelane), and of aluminium (bauxite).	Eluvial gravels formed near the outcrop of veins (e.g. those of gold, cassiterite, wolfram, galena and zinc ores).	

REVIEWS.

I.—The Palæontographical Society, 1847–1914.

Issue of Vol. LXVII, for 1913. Agents for the Society, Dulau & Co., Ltd., 37 Soho Square, London, W.

Contents.

1. British Graptolites. By Miss Elles & Miss Wood (Mrs. Shakespear). Edited by Professor Lapworth. Part X. pp. 487–526, pls. l–lii.
2. A Monograph of the British Palæozoic Asterozoa. By W. K. Spencer, B.A., F.G.S. Part I. pp. 1–56, pl. i.
3. The Lower Palæozoic Trilobites of Girvan (supplement). By F. R. Cowper Reed, M.A., Sc.D., F.G.S. pp. 1–56, pls. i–viii.
4. The Pliocene Mollusca of Great Britain (supplementary to S. V. Wood's Monograph of the Crag Mollusca). By F. W. Harmer, F.G.S., F.R.Met.S. Part I. pp. 1–200, pls. i–xxiv.
5. The Ganoid Fishes of the British Carboniferous Formations. By Ramsay H. Traquair, M.D., LL.D., F.R.S. Part I, No. 7: Palæoniscidæ. pp. 181–6, with title-page and indexes.
6. Title-page and Systematic Index to complete a Monograph of the Fishes of the Old Red Sandstone of Britain. By R. H. Traquair, M.D., LL.D., F.R.S.

THE Council of the Palæontographical Society, its officers and subscribers, have reason for congratulation on the issue of their sixty-seventh annual volume (for 1913), under date of February, 1914. Age has not in any way diminished the lustre or lessened the artistic beauty or scientific value of the work published from year to year by this most important Society, and, despite the losses sustained both amongst its distinguished authors and its valued subscribers, new authors arise to add fresh contributions to its pages and new subscribers to replenish its funds, although the latter need to be greatly increased if similar splendid volumes, such as that now lying before us, are to be produced in this and future years.

1. The sixty-seventh volume opens with the tenth part of the monograph on British Graptolites, by Miss Elles & Miss Wood (Mrs. Shakespear), edited by Professor Lapworth. This valuable work was commenced in the fifty-fifth volume, for 1901, and has been continued (with only three intervals of a year each) up to the present time. It will probably be completed in another part. The Graptolites form a remarkable group which students of the existing Hydromedusæ generally dismiss in a very summary fashion as "a class known only in a fossil state, divided into three orders, which possibly bear but little genetic affinity to one another": 1, the Dendroidea; 2, the Graptoloidea—(*a*) Monoprionidæ, (*b*) Diprionidæ; 3, Retioloidea. But as among existing forms referred to this class their life-history has yet largely to be worked out, we may rejoice to find that by the combined labours of a large number of able investigators the Graptoloidea have now been well and carefully defined and have become, as *zonal indices*, of the highest importance in the Lower Palæozoic rocks.

The first detailed arrangement in successive chronological zones was made by Lapworth in his memoir "On the Geological Distribution of the Rhabdophora" (Ann. Mag. Nat. Hist. (5), vols. iii–vi, 1879–80).

A comparison of this memoir with the present monograph, as summarized in Table A, pp. 516–25, and Table B, p. 526, of this part, affords a striking index of the advance in our knowledge of the Graptoloidea during the thirty-three years interval which separates these works. In the earlier memoir the species and varieties numbered 284, distributed over some 20 Graptolite zones; the zones are now increased to 36, and the species have risen to 372.

All praise is due to the two lady authors, who, under the editorial criticism of Professor Lapworth, have so ably carried on the task of preparing this excellent monograph, now nearly completed.

2. Under the title of "British Palæozoic Asterozoa", Mr. W. K. Spencer, a new author, commences part i of a new work, and by way of introduction gives us a charmingly illustrated description of the minute anatomy of the hard parts of these interesting ancient star-fishes and their modern allies, one plate and thirty-one text-figures being used to render his explanations and nomenclature of parts clear to the reader. A bibliography of eighty-three works, relating to the literature of the subject, is also given.

3. Mr. F. R. Cowper Reed adds a supplement to his monograph of 1906 on "The Lower Palæozoic Trilobites of Girvan, Ayrshire", in order to describe twenty-three new species and three new varieties, obtained by Mrs. Gray, of Edinburgh, and to make sundry emendations and additions to his work. Eight excellent plates are also given of these new forms.

4. Mr. F. W. Harmer, a second new author, contributes part i of a monograph on Pliocene Mollusca (being by way of a supplementary monograph to S. V. Wood's Crag Mollusca commenced in 1847). Mr. Harmer, together with other workers, have added between six and seven hundred species to the Crag fauna of Walton (but chiefly from Little Oakley), from which, in Wood's time, less than 150 species were known. Mr. Harmer's contribution to this volume occupies 200 pages, and the illustrations fill twenty-four collotype plates, which being photographed from the actual specimens gives them a trustworthiness and reliability which the student of species will greatly appreciate. After an introductory section on the localities and the recent literature we come to the description of the Terrestrial Mollusca (twenty-four) and a number of freshwater forms (twenty-four), also from the Crag deposits. Following upon these we have the Marine Mollusca of the Crag, commencing with the Gasteropoda (pp. 49–200). But we must revert to Mr. Harmer's admirable monograph later, as our space is limited.

5 and 6. These consist of the closing pages on the Ganoid Fishes of the British Carboniferous Formations (with the title-pages and indexes) and the fishes of the Old Red Sandstone—closing the labours of our old friend and fellow-contributor, Dr. R. H. Traquair, F.R.S.

The indices to these volumes have been most carefully and kindly contributed by our able Secretary, Dr. Arthur Smith Woodward, F.R.S., whose valuable services in the production of this large and handsome volume all palæontologists will most gladly and gratefully acknowledge.

II.—Catalogue of the Mesozoic Plants in the British Museum. Part V: The Cretaceous Flora. Part I: Bibliography, Algæ, and Fungi. By M. C. Stopes, D.Sc., etc. pp. xxiv, 286, with 2 plates and 25 text-figures. London: Dulau & Co., 1913. 12*s.*

It is now ten years since the last part of the Catalogue of Mesozoic Plants was issued. The first four parts, by Professor Seward, dealt with the Jurassic and Wealden Floras, and the work is now being continued into the Cretaceous by Dr. Stopes. The present volume consists mainly of an exhaustive bibliography of the flora of the period, which unfortunately could only be brought up to the end of 1910. The list of species, which is not intended to be critical, contains references as far as possible to every Cretaceous plant, with the name and horizon originally given. The Wealden of Europe is omitted, since it was dealt with by Professor Seward, but the lower Cretaceous of North America, with its rich flora, is included. Though many cross-references are given in cases where species have been removed from one genus to another, no attempt has been made to make the list complete in this respect, as Dr. Stopes only includes "any renaming that was enlightening, or accompanied by any original work on the specimen". Nevertheless, the list will form a useful work of reference for future workers in this department of fossil botany.

The descriptive part of the catalogue deals only with the Algæ and Fungi, and owing to the scarcity of well-authenticated fossil examples of these groups, there is not much to be said about them. In the case of the algæ the calcareous forms are the most interesting, since their structure can often be studied under the microscope, while recently their importance as rock-builders has been much discussed. Several genera of the Siphoneæ are represented in the Cretaceous, besides the red alga *Lithothamnion.* The remaining "algæ", apart from diatoms, are impressions only, and though some are probably of an algal nature the great majority are extremely doubtful. Dr. Stopes gives a list of seventy-eight "species" which may be dismissed as mere tracks or indeterminable specimens.

The Fungi are even more poorly represented. Only four of those enumerated occur in a petrified state, and one of these, *Trametites pini* (Conw.), is merely a mycelium, while *Petrosphæria japonica*, Stopes & Fujii, is little better, and shows no reproductive organs by which its family might be determined. In *Trichosporites Conwentzi*, Felix, spores are associated with the hyphæ, but the illustration shows no evidence of attachment. The only well-preserved species is that called *Pleosporites Shirainus*, Suzuki, but even here the apparent asci contain no ascospores, so that the generic affinities are doubtful. Dr. Stopes suggests that different "biological species" of this fungus may have been adapted to the different species of *Cryptomeriopsis* in which it occurs, but are such "biological species" found among Ascomycetes at all? The other "phenomena described as fungi" are markings on leaves, often of a very doubtful nature. Dr. Stopes uses Gothic type for the names of "fossil plants for which there is no good, scientific reason for association with given families and genera, and to which, nevertheless, names indicative of such affinities have been given", and most of the fungi might well have been black-listed in this way.

The Introduction contains a short account of Cretaceous plant-bearing deposits in various parts of the world, with a useful table giving approximate correlations of the different beds.

III.—Paléontologie Végétale: Cryptogames Cellulaires et Cryptogames Vasculaires. By F. Pelourde. pp. 360, with 80 text-figures. Paris: O. Doin et fils, 1914. 5 fr. London: Dulau & Co.

THIS is the first volume to appear in the palæontogical section of a new Encyclopédie Scientifique. The aim of the series, which is to comprise about a thousand volumes, is to provide a critical summary of the present state of scientific knowledge in all its branches. There are to be two more volumes on palæobotany, one dealing with gymnosperms and the other with angiosperms and general conclusions, and these will in some respects be more interesting than the first, for they will deal with less familiar ground. We already have several excellent textbooks of fossil botany, and it might be thought that there was little room for the present compilation. It will, however, prove extremely useful to students, for it is of a handy size, and will easily slip into the pocket, and the facts are on the whole well chosen and concisely arranged. A marvellous amount of information has been compressed into a small space, and the account of the stem structure of *Sigillaria*, for example, is particularly clear, as also is the section dealing with the ferns. It is a pity that many of the illustrations, especially the reproductions of photographs, are so poor.

In matters of detail a few criticisms may be made. Thus in the geological table the Silurian system is divided into Cambrian, Ordovician, and Gothlandian, each being apparently equivalent to each of the six subdivisions of the Devonian, which would be rather misleading to the non-geological reader. *Lepidodendron saalfeldense* and other petrified plants from Saalfeld, Thuringia, are undoubtedly of Lower Carboniferous and not Devonian age (p. 118) and the genus *Megalopteris* was erroneously described by Dawson as Devonian (p. 224). In view of our ignorance as to the limits of the Pteridospermæ, where fronds alone are concerned, it is a rather sweeping assertion that the immense majority of Pecopterids belonged to the Marattiales, while many of the supposed Marattiaceous sporangia may well be microsporangia of Pteridosperms. There is very little known of fossil thallophytes and bryophytes, and in Dr. Pelourde's necessarily short account such a doubtful specimen as Matthew's supposed Palæozoic lichen might well have been omitted.

The bibliography calls for some comment. The paging is usually and dates occasionally omitted, and such a reference as "Lesquereux. Geol. of Penn'a, II" is quite inadequate. Several references given in the text do not appear in the bibliography. One of Williamson's papers is credited to Mr. Kidston ("Kidston, 3"). The practice of omitting authors' initials leads to the confusion, for example, of the late German palæobotanist, C. E. Weiss, with the present professor of botany at Manchester; while similarly (see index) no distinction is made between Professor W. P. Thomas and Mr. Hamshaw Thomas of Cambridge.

In other respects, however, Dr. Pelourde has produced an excellent condensed account of fossil plants, as far as the Pteridophytes, in the light of modern knowledge.

IV.—Australasian Fossils: A Student's Manual of Palæontology. By Frederick Chapman, Palæontologist to the National Museum, Melbourne. pp. 341, 150 figures, and map. Melbourne, Sydney, Adelaide, Brisbane, and London: George Robertson & Co., 1914.

MR. CHAPMAN has in numerous memoirs added largely to our knowledge of the fossil flora and fauna of the Southern Hemisphere, and, in the work now before us, has conferred a great boon upon all students of geology in the Dominions of Australia and New Zealand. The necessity of such a work as the present will be manifest to everyone who remembers that in all the published geological treatises the examples and illustrations given are those of the fossils of Europe and North America; the descriptions and figures supplied by Mr. Chapman will serve to admirably redress this grievance of geological students at the Antipodes.

In a short, but very clear, introduction to the book Professor Skeats admirably summarizes the principles of palæontological science. In the body of the work the author, after some preliminary chapters, gives an account of the fossils of each of the great classes of plants and animals, the arrangement in each class being a stratigraphical one, while the very numerous figures admirably illustrate the text. At the end of each chapter there is given a list of the common or characteristic forms of the group described, with complete series of references to the literature dealing with the class of organisms.

The work closes with an appendix on the collection and preservation of fossils, to which is added a list of fossil localities, illustrated by a map of Australia and New Zealand, on which the position of these localities is shown. The work cannot fail to be of great service, not only to students, but to all interested in geological studies on the other side of the globe.

V.—Tennessee State Geological Survey.

Bulletin 16. The Red Iron Ores of East Tennessee. By Ernest F. Burchard. pp. 173, with 17 plates (including 5 maps) and 30 figures in the text. 1913.

THIS bulletin describes the ore-deposits situated in the northern part of the Chatanooga District of East Tennessee, and discusses very briefly the ore-bearing formations and the rocks immediately associated with them. Deposits of ore occur in three formations: the Tellico Sandstone (Ordovician), the Rockwood formation (Silurian), and the Grainger Shale (Carboniferous). The deposits in the Grainger Shale are of very little importance. The ores of the Tellico Sandstone are 'replacement ores', and are due to the leaching out by surface agencies of the calcium carbonate from beds of ferruginous limestone. The deposits of the Rockwood formation belong, however, to the 'Clinton type' of iron-ore; they occur as lenticular beds of hematite analogous to the strata of sandstone, shale, and limestone with which they are associated, and consist of a mixture of 'fossil ore' and 'granular ore'.

Fossil ore consists of aggregates of fragments of crinoids, corals, brachiopods, and trilobites, many of which still consist of calcite, but in places they are now wholly composed of ferric oxide. Granular ore is a variety of oolitic ore, consisting of flattened grains lying with their flat sides parallel to the bedding and cemented by ferric oxide; the grains often contain a nucleus of quartz.

These hematite beds were formed by the deposition in the waters of shallow bays or lagoons of sediments containing iron together with calcium carbonate, silica, and alumina. Much of the calcium carbonate was deposited as fragments of fossils. There is no evidence that the iron was introduced from other beds of the Rockwood or any other formation. It is held that the replacement of calcium carbonate by ferric oxide may have taken place quite early in the history of the deposits, and that the unweathered ores were formed in essentially their present condition, contemporaneously with the associated sandstone and shale.

The distinction between the mode of formation of 'replacement ores' and of ores of the Clinton type is one of great economic importance, for those of the Clinton type will not be expected to show any regular decrease of iron content in depth, which is usually the case with 'replacement ores'.

The bulletin contains detailed descriptions and sections of the mining prospects, and concludes with some useful notes on mining and on the iron industry.

VI.—Water and Volcanic Activity. By A. L. Day & E. S. Shepherd. Bull. Geol. Soc. America, vol. xxiv, pp. 573–606, pls. xvii–xxvii.

In a previous issue of this journal there appeared a review of a very striking work entitled *Recherches sur l'exhalaison volcanique*, by Albert Brun, a chemist of Geneva. Brun was impressed by the frequent absence of evidence for the widely accepted aqueous theory of volcanoes; he had accordingly devoted his spare time to the study of various active craters, and had been led to the conclusion that in paroxysmal eruptions water does not exist among the gases emanated. Much of the evidence for this conclusion was derived from the study of Kilauea, where Lowthian Green had been led to the same conclusion as Brun as early as 1887. The American geologists have taken up the challenge and have sought to make a careful examination of the emanations from Kilauea in order to test the validity of Brun's conclusions.

The gases examined by Brun were collected by means of tubes, the end of which was 250 feet above the surface of the lava; these gases were consequently already *burnt* and mixed with air. To obtain unburnt gases the authors made descents into the crater, at considerable danger to themselves, and pumped the gases through a set of tubes the end of which, cased in iron, extended for a foot into a vent in a dome of lava on the crater-floor. In fifteen minutes, during which 1,000 litres of gas may have passed through the glass tubes, the authors obtained about 300 c.c. of water. A second attempt was made to collect the gases in vacuum tubes and so find the relative proportions of the constituents, but the experiment was vitiated by access of air from another vent; however, the figures obtained indicate that water was present to the extent of 26 per cent by weight. It is therefore clear that water does play an important rôle in the emanations from Kilauea, and that Brun's conclusions in this respect are false. Many of Brun's arguments are based on observations of the cloud over the lava in the crater pit of Kilauea and on hygrometric measurements, but it is shown that his deductions from these observations were incorrect.

Further interesting deductions may be made from the study of the emanations of Kilauea. The gases detected include nitrogen, hydrogen, water, carbon dioxide, carbon monoxide, hydrogen, and sulphur, with traces of chlorine, fluorine, and, possibly, ammonia. These gases issue from vents in the lava at a temperature near 1,000° C., a temperature at which they cannot possibly be in equilibrium under atmospheric pressure. Diminution in pressure may cause interactions which probably produce a heating effect far exceeding the cooling effect due to expansion; thus the gases may be hotter at the surface than in depth. In support of this idea it is noted that the temperature of the lava rises with the quantity of gas given off. With regard to the origin of the water, the authors find themselves unable to conceive of any mechanism whereby atmospheric or surface waters could reach the magma basins. Further, the very important fact that *argon* is absent in the emanations of Kilauea proves that atmospheric gases have not reached the magma basins. The water of the emanations "must be considered as an original constituent with as much right as the sulphur or the carbon".

VII.—Directions for the Collection of Geological Specimens. By Dr. J. W. Evans, LL.B., F.G.S. Colonial Office, Miscell. No. 283.

UNDER this title the Colonial Office have issued a tract by Dr. J. W. Evans, giving explicit instructions as to what to do and what to avoid. It cannot be too often said that many of those who travel to little-visited parts of the world are entirely ignorant of the simplest geological knowledge, and with every intention of bringing home specimens often collect useless material. In this tract the traveller is told exactly what is likely to be of use, how to obtain it, how to label and pack it, and how to make his notes on what is collected. The few pages (twenty) will hardly form impedimenta in his baggage, and the knowledge he will obtain from a perusal of the tract will, even if he does not happen to do any collecting, greatly increase the interest of his wanderings. The tract is referred to as Colonial Office, Miscell. No. 283, and as no price is attached can be had for the asking.

VIII.—Canada: Department of Mines.

1. Austin Brook Iron-bearing District, New Brunswick. By E. Lindeman. pp. 15, with 3 plates, 5 figures, and 3 maps. 1913.

THIS report is based on a magnetometric survey of the areas, of which a preliminary report was issued in 1906. The ore consists of very fine-grained siliceous magnetite mixed with a considerable amount of hematite. It occurs as dyke-like masses in a quartz-porphyry, which is itself intruded into slates, possibly Devonian in age. Analyses are given of eight samples of ore, and there are details of the cores obtained from four borings. The maps accompanying the report include magnetometric and geological maps on a scale of 400 feet to the inch, and a smaller scale map showing the location of the district.

2. Magnetite Occurrences along the Central Ontario Railway. By E. Lindeman. pp. 23, with 9 plates and 19 maps. 1913.

The deposits of magnetite here considered occur between Central Ontario Junction and the village of Bancroft, a distance of about 60 miles. The greater part of this area is occupied by Archæan rocks, consisting of crystalline limestones, para-gneisses, schists, and amphibolites, intruded by granite, syenite, diorite, and gabbro, and in places overlain by the lowest beds of the Palæozoic Series.

The magnetite occurs as irregular masses interbanded with crystalline limestones and schists usually along or near their contacts with intrusive diorite; they are regarded as a result of the contact action of the igneous rocks on the limestone, as they contain many minerals characteristic of this type of metamorphism. In addition to this there are small occurrences of titaniferous magnetite representing local concentrations in a gabbro.

The area being largely drift-covered, the careful use of a systematic magnetometric survey has been of the greatest value. The report is accompanied by eighteen maps, magnetometric and geological, on a scale of 200 feet to the inch, and by an index map showing the location of the deposits. The various deposits and mines are described in detail, but there seems little hope of any of the deposits being of great economic importance.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *February* 25, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "Acid and Intermediate Intrusions and Associated Ash-Necks in the Neighbourhood of Melrose (Roxburghshire)." By

Rachael Workman McRobert, B.Sc. (Communicated by E. B. Bailey, B.A., F.G.S.)

This communication deals with the igneous rocks which fall within an area about 7 miles square, included in Sheet 25 of the Geological Survey map of Scotland, and which lie in the neighbourhood of Galashiels, Selkirk, and Melrose. The age usually assigned to the igneous intrusions is a late period in the history of the 'plateau-eruptions' of Calciferous Sandstone times, and thus corresponds to those of the trachytic lavas and intrusions of the Campsie and Renfrewshire Hills.

The relation of the igneous rocks to the Old Red Sandstone is discussed, and new localities are cited where a protective covering of igneous rocks has resulted in the preservation of small outliers of Old Red Sandstone, far removed from the main outcrop of the formation.

The main portion of the paper deals with the petrology of the igneous rocks, which occur as laccolites and sills, as dykes having for the most part a north-easterly direction, and in volcanic necks.

The chief rock-types present in the area described may be summarized as follows: Porphyritic and non-porphyritic sanidine-trachytes, quartz-trachytes, riebeckite-felsites, quartz-porphyries, basalts, and volcanic agglomerates. The sanidine-trachytes present a number of varieties, characterized either by the presence of fresh riebeckite, by the presence of ægirine-augite and olivine, or by the absence of any fresh ferromagnesian minerals. The more acid types described may be regarded as standing midway between the phonolites and trachytes of the same age which occur south-east of Hawick and those of East Lothian.

In addition to the description of the various rock-types which occur as isolated sills and dykes, the geology of the Eildon Hills is discussed in some detail, and a petrographical account is given of the rocks in that region. The author has traced as far as possible the distribution of the various rock-types, and has come to the conclusion that the Eildon Hills form the eastern section of a composite, complex laccolite. A basaltic neck has been met with in the Eildon Hill complex, and appears to cut through the more acid intrusions which form the main portion of the Eildon Hills. The record of riebeckite in the rocks of this region has been considerably extended.

The salient features of the suite of rocks described are the high content of alkalies and the presence of soda-bearing minerals such as riebeckite, ægirine-augite, primary albite, and soda-orthoclase. Nepheline, however, though its presence might be expected in some instances, was found to be absent from most of the rocks.

2. "Correlation of Dinantian and Avonian." By Arthur Vaughan, M.A., D.Sc., F.G.S.

The present paper records the results of applying the time-scale deduced from the South-Western Province to the Belgian sequence, and shows that the faunal succession is practically the same in both provinces. Even the specialized and locally exaggerated facies which form so striking a feature of the Belgian Province (such as the 'petit granit', the 'Waulsortian', and the '*sublævis* oolite') have been discovered at certain points of the South-Western Province, and they are adumbrated at many others. [If, furthermore, we extend our researches and compare the Midland and Northern developments of England and Wales with that of Belgium, striking identities are observed; for example—

The 'Brachiopod Beds' of the Midlands and of Visé are identical.
The lower 'knolls' of the Clitheroe area are typical 'Waulsortian'.]

The following are the most important conclusions from the author's work in Belgium:—

(1) *Physiographical Phenomena.*—The lateral variation of Mid-Avonian lithology is strikingly exhibited in a diagram. Minute correlation of the Belgian sequence with that of the South-Western Province demonstrates that the periods of partial emergence, of the west of the South-Western Province and of the east of the Belgian Province, took place consecutively and not simultaneously, namely: in the South-Western Province at the close of C_1 time, in Belgium at the beginning of Viséan time. At the latter period England and Wales, outside the South-Western Province, had sunk below the Carboniferous sea. [Simultaneously, however, Ireland was, like Belgium, under emergent conditions.]

(2) *Palæontological Phenomena.*—The palæontological section contains descriptions of several gentes that are common in Belgium, but rare in Britain. The most interesting portion of the section is, however, that which deals with the evolution of the important Carboniferous corals and brachiopods. Two illustrations were selected, and were shown as lantern-slides:—

1. Phylogenetic history of *Caninia cylindrica.*
Belgium only { K. *Endophyllum.* / Z. *Caninia hastierensis* (Endophylloid).
Migration into Britain at γ—*C. cylindrica*, mut. γ.
Britain and Belgium . δ and S—mature (Campophylloid) *Caninia.*

2. Fragments of the history of *Spiriferina octoplicata*, showing variation of relative strength of ribs (departure from normality of early stages)—the essential characters fixed.

These facts concerning migration and evolution are, unquestionably, the most important results of extending the area of observation.

The author has received continuous and invaluable assistance from Professor G. Delépine and from Mr. E. E. L. Dixon; he is also very deeply indebted to the recent works of Professor Delépine and Dr. A. Carpentier (Northern France), from which he has cited freely.

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2. *March* 11, 1914.—Dr. A. Smith Woodward, F.R.S., President, and afterwards Dr. H. H. Bemrose, J.P., Vice-President, in the Chair.

Mr. E. T. Newton, in exhibiting a series of small mammalian and other remains from the rock-shelter of La Columbière, near Poncin (Ain), said that, during the year 1913, Dr. Lucien Mayet and M. Jean Pissot were working systematically at the prolific deposits of this locality, and towards the end of the year made known the discovery of a number of incised bones and stones, representing the human form as well as several animals. This discovery was published in the C. R. Acad. Sci. Paris (vol. clvii, p. 665), and some account of it, with several figures, appeared in the *Illustrated London News* for November 1, 1913.

The upper part of the deposit is referred to the Neolithic and Magdalenian ages; but below this, at a depth of $6\frac{1}{2}$ feet, a bed (10 inches thick) was found, which yielded the incised drawings above mentioned, as well as numerous mammalian remains and flint implements; and this is regarded as of Aurignacian age. Immediately below the last-mentioned bed a deposit of sand and small rock-fragments was penetrated to a depth of 10 feet, and this deposit, also referred to the Aurignacian, was found to contain an enormous number of bones of small mammals and other animals. Some twenty species have already been recognized by the discoverers.

The large number of small bones now shown were obtained by the exhibitor in sifting about 1 cubic foot of this lower, remarkably prolific, deposit, which had been sent to him by Dr. Lucien Mayet, of Lyons.

The following communication was read:—

"On an apparently Palæolithic Engraving on a Bone from Sherborne (Dorset)." By Arthur Smith Woodward, LL.D., F.R.S., Pres.G.S.

The author is indebted to Mr. R. Elliot Steel, of Sherborne School, for the opportunity of studying a fragment of bone bearing an incised drawing of the fore-part of a horse in the style of drawings already well known from several habitations of Palæolithic man. The specimen was found by schoolboys in an old mound of débris from a quarry in the Inferior Oolite near Sherborne. Nothing is known of the circumstances under which it originally occurred; but the situation of the quarry is in a small dry valley, on a steep slope facing south-westwards, and the bone may perhaps have been removed with the remains of a rock-shelter. No associated specimens of any interest were recovered; but at the lower end of the same valley, about a quarter of a mile distant, teeth of mammoth and woolly rhinoceros have been found. Like the only other British specimen hitherto discovered—that described by Professor Boyd Dawkins from the Creswell caves—the drawing is made on a fragment of rib; and the neck of the horse is fringed by fine lines, which indicate the short hog-mane usual in sketches made by the Palæolithic race.

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3. *March* 25, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund for the present year to Percy George Hamnall Boswell, B.Sc., F.G.S., who proposes to investigate the stratigraphy and petrology of the Lower Eocene strata of the north-eastern portion of the London Basin.

Professor J. W. Judd, C.B., F.R.S., gave the following general account of the geology of Rockall[1]:—

Rockall is a small isolated rock in mid-Atlantic, lying 184 miles west of St. Kilda; it has a circumference of only 100 yards and a height of 70 feet, and, except in the very calmest weather, is quite inaccessible. It is the haunt of sea-birds and, with its whitened top, resembles a sailing ship, for which it has often been mistaken. The rock rises from a bank (the 'Rockall Bank') upon which there are several dangerous reefs.

More than 300 years ago it was reported that a large island occupied the site of Rockall, and, for a hundred years or more, all Atlantic charts represented this island, which was named 'Busse Island', with a number of other islands and islets, as present in the North Atlantic. Taking these supposed facts in connexion with the famous classical stories of an 'Atlantis', the theory was often advanced that the North Atlantic was an area of subsidence, and that the reported islands—and, in the end, Rockall—were the last vestiges of the famous vanished continent. Modern research has, however, quite disposed of this theory.

Nevertheless, Rockall is of considerable interest, especially to geologists. In 1810 Basil Hall, then a young officer in H.M.S. *Endymion*, obtained a fragment from this rock, which later found its way into the collection of the Geological Society. More than thirty years afterwards the specimen was recognized; it was then mislaid for another thirty years, and in 1895 was brought to me by the late Professor T. Rupert Jones.

He not only carefully studied all the literature connected with Rockall, but was able to trace two other specimens of the rock, the loan of which he obtained and brought to me. They had been procured by two of the officers of H.M.S. *Porcupine* in 1868 during the survey of the North Atlantic. The microscopic study of these specimens shows that in Rockall there exist rocks of exceptional interest, which are not represented in our Islands, but have analogies in the Christiania district of Norway, where they have been so well studied by Professor W. C. Brögger. These rocks, as shown by microscopic study and by a chemical analysis made by Mr. Makins, consist essentially of three minerals—quartz, the felspar albite, and the rare soda-pyroxene ægirite, with its dimorphous form acmite. The rock, therefore, resembles the soda-granite and the grorudite of Professor Brögger, but, in deference to the opinion of the distinguished Norwegian petrographer, a distinct name was given to it.

In 1896 an attempt was made to obtain further specimens of the rocks of this islet by members of the Royal Irish Academy; but, although many valuable observations were recorded, it was found, after two voyages had been made to Rockall, quite impossible to land and obtain specimens.

Dredging operations have yielded many specimens from the Rockall Bank, and these were examined by the late David Forbes and Professor Grenville A. J. Cole. The abundance of basalt fragments among these dredgings suggests the possibility of Rockall belonging to the same petrographical province as St. Kilda, Iceland, the Inner Hebrides, and the North of Ireland; hitherto, I believe, no rocks resembling 'rockallite' have been found in this province. On the other hand, the existence of borolanite and other alkaline rocks in the Northern Highlands suggests the possibility of Rockall being the western extension of a much older province, which includes the Christiania district and the Scottish Highlands.

Some months ago Professor Iddings and Dr. Washington represented to me the desirability of a more detailed analysis of this rock. One of the two small fragments available was, by the advice of Professor Watts, sent to America by the Council of the Imperial College of Science and Technology, to whom they

[1] For an account of "Rockall Island and Bank" see GEOL. MAG., 1899, pp. 163–7, and Trans. Roy. Irish Acad., vol. xxxi, pt. iii, pp. 39–98, pls. ix–xiv, 1897.

belonged, and the paper now about to be read gives the result of the study of this minute specimen by Dr. Washington.

The following communication was read:—

"The Composition of Rockallite." By Dr. Henry S. Washington, For. Corr. G.S.

The paper centres around a detailed chemical analysis made by the author of the type-material of rockallite, an igneous rock of exceptional chemical and mineralogical composition.

A petrographical account is given of the rock, with special reference to the influence of the constituent minerals upon the bulk-analysis.

Rockallite has a fine-grained granitic structure, and is composed of about equal amounts of colourless quartz, alkaline felspar, and soda-pyroxene. The pyroxene is of two kinds, a bright grass-green ægirite and a pale yellowish-brown acmite. Some zircon is present, but not to more than a tenth of 1 per cent of the rock.

A chemical analysis has been made with the greatest care, according to the methods advocated by Hillebrand and the author, zirconia and the rare earths being especially looked for. The main results of the analysis confirm those of Makins, but several new points of interest have presented themselves. The outstanding features of the rock appear to be the high percentages of silica, ferric oxide, and soda, and the low percentages of alumina, ferrous oxide, magnesia, lime, and potash. The special interest of the new analysis, however, lies in the detection of zirconia and cerium oxide in unexpectedly large amounts, the percentage of cerium oxide being larger than that from any known igneous rock, with the exception of the nepheline-syenite from Almunge in Sweden.

The author has calculated the norm from the old and the new analyses, and finds that the rock falls into the subrang rockallose with the general symbol III. 3. I. 5. He notes, as indicating the exceptional character of the rock, that these analyses are the only representatives of the subrang rockallose among the 8,000 analyses of igneous rocks that he has now collected.

The author concludes with a discussion of the affinities of rockallite, and a consideration of the probable chemical composition of the ægirite and acmite. He clearly proves that the zirconia and cerium oxide enter into the composition of the pyroxenes.

II.—Mineralogical Society of London.

March 17, 1914.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

F. P. Mennell: On an occurrence of Bornite Nodules in shale from Mashonaland. The ore-body of the Umkondo mine in South-East Mashonaland consists of a bed of shale through which are scattered nodules of bornite, most probably pseudomorphous after concretionary pyrites. The enclosing rocks are of the same age as the Waterberg Series of the Transvaal, and contain pseudomorphs after salt in some of the shale bands. The occurrence of copper and salt at nearly the same horizon is paralleled in the Lower Keuper beds of Europe.—A. Scott: Augite from Bail Hill, Dumfriesshire. It occurs in crystals, which are black in colour, but yellowish-green in thin sections, and of two types, simple and twinned, and have the axial constants $a : b : c = 0{\cdot}5844 : 1 : 1{\cdot}0932$, $\beta = 105° \ 48'$, and refractive indices 1·708, 1·713, 1·728. Sections parallel to the plane of symmetry show the hour-glass structure characteristic of titaniferous augite.—Dr. G. T. Prior: On a Sulpharsenite of Lead from the Binnenthal. Analysis of the crystals, on which the prism zone alone was developed, showed that the composition corresponded to the formula $3 PbS . 2 As_2S_3$, which is that attributed to rathite; crystallographically, however, the crystals seem nearer to dufrenoysite.—Dr. G. T. Prior: On Phacolite and Gmelinite from County Antrim. In both instances analysis of these minerals, which are varieties of the same species, differing in habit of crystal, showed an excess of hydrated silica over the composition represented by the formula $(Ca, Na_2) Al_2 Si_4 O_{12} . 6 H_2 O$.

III.—Edinburgh Geological Society.

March 25, 1914.—Dr. John S. Flett, F.R.S., President, in the Chair.

1. "On a Visit to the Klondyke Goldfields." 2. "The Glaciation of Alaska." (Illustrated.) By H. M. Cadell, B.Sc., F.R.S.E.

The object of the papers was to give an account of the Klondyke goldfields and the glaciers of Alaska visited by the author last autumn.

During last century there had been a great shrinkage in the glaciers, but some of them had begun to advance since the great earthquake in September, 1899. The traces of the earthquake were still very distinct. Parts of the coast were upraised 40 feet in places, and gaping fault-fissures were plainly seen. On the way from the watershed towards Dawson City and Klondyke the signs of glaciation became less and less, and in the goldfields it was clear there had never been any glacial action at all, though it lay so far north.

The old plain gravels in the Klondyke valley and other places had never been disturbed since Pliocene times, except by changes in the river system that had occurred in consequence of alterations of the level of the land. This absence of ice was due to the dryness of climate in the Glacial period in that region, and not to a warmer climate. The gold-bearing gravels were frozen solid to a depth of 100 feet, and contained bones and tusks of mammoths and other animals. There were two sets of placer gravels, one in the bottom, and another higher up on the side of a few of the valleys. The older gravels had no animal remains in them, and were nearly white in colour. The level had been upheaved 700 feet, and the rivers had cut out deeper glens before the newer gravels were produced, and the gold was washed out and deposited in the beds of the creeks, where it had lately been, and still was being worked, but on a smaller scale than in 1900.

The total yield of the goldfield was about £30,000,000, and in 1913 there was still a production of £1,000,000 by dredging and hydraulic sluicing companies with a large capital. Klondyke was no longer a poor man's goldfield, and there was still a good deal of gravel that could be profitably worked by means of extensive plant.

OBITUARY.

GEORGE SHARMAN,

late Palæontologist to the Geological Survey.

BORN SEPTEMBER 27, 1832. DIED MARCH 28, 1914.

WE regret to have to announce the death of Mr. George Sharman, who for many years was Palæontologist to H.M. Geological Survey, but whose name may be little known to the present generation of geologists, seeing that his retirement from official duties took place some seventeen years ago. Mr. Sharman, after being at the British Museum for a short time, joined the Survey in 1855, was promoted in 1865, and became senior palæontologist in 1882, which post he held until his retirement at the end of 1897. Mr. Sharman did not devote himself to what is usually spoken of as original work, that is to say, he did not publish papers, but his whole energies were devoted to his official duties, and for many years a large part of the fossils collected by the Survey officers were determined by him, and the results appear in the Survey memoirs. He was particularly keen in the study of the fossil Brachiopoda, and Dr. Davidson's ponderous volumes, published by the Palæontographical Society, were his familiar textbooks. Mr. Sharman was of a peculiarly retiring disposition, and consequently was seldom seen at any of our Society meetings, but his kindly disposition and sterling integrity endeared him to all who were privileged to work with him, and many geologists will remember the kind friend at Jermyn Street Museum who years ago helped them in naming the fossils they had collected. After his retirement he lived quietly at Tooting and for some years has had very indifferent health, notwithstanding which he attained to a length of life beyond the usual span.

MISCELLANEOUS.

CONFERENCE OF BRITISH GLACIALISTS.—At a meeting of the Yorkshire Geological Society, held at Leeds on Thursday, March 19, a communication from the President (Mr. R. H. Tiddeman) was read in which it was suggested that the time was now ripe for a review of the whole question of British Glacial Geology, and that for this purpose it might be desirable to call a conference. The suggestion was received with enthusiasm, and arrangements are to be put in hand at once for such a conference to be held in Leeds in the autumn and will last a week. Excursions will be made during the day to various centres of importance in connexion with the glaciation of the North of England, and the evenings devoted to papers and discussions. Glacialists from all parts of the country will be invited to attend. A committee was elected to make all the necessary arrangements, consisting of the President, Professor P. F. Kendall, Mr. T. W. Stather, Mr. T. Sheppard, Mr. A. Wilson (treasurer), and Mr. A. Gilligan (secretary).

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THE

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OR

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JUNE, 1914.

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

No. VI.—JUNE, 1914.

ORIGINAL ARTICLES.

THE COMPLETION OF FIFTY YEARS OF THE *GEOLOGICAL MAGAZINE*.

THE publication of the 600th Number of the GEOLOGICAL MAGAZINE completes fifty years of its existence, and the Editor gladly avails himself of the occasion to express to his numerous friends and colleagues his most cordial thanks for their unfailing and generous support since 1864. Without their aid he would have been on many occasions at a loss to sustain the difficult task of providing for the monthly issue of the Magazine through so many years.

It is very gratifying to the Editor that the Rev. Osmond Fisher, M.A., F.G.S., Sir Archibald Geikie, K.C.B., P.P.R.S., F.G.S., Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S., and Professor Edward Hull, M.A., LL.D., F.R.S., F.G.S. (who represent the contributors to the 1864 volume) have sent him letters of congratulation on his Jubilee; for, alas! by far the larger number of the early friends and supporters of the GEOLOGICAL MAGAZINE have "joined the majority". The ranks of the geologists have, nevertheless, maintained their strength, as will be seen by a reference to the retrospect of the work in the forty years from 1864 to 1903, in which a splendid record is furnished of geological and palæontological contributions, summarized by the late Horace B. Woodward and the Editor.[1] The subsequent decade (1904–14) has been no less prolific in good work. Indeed, one may venture to maintain that the quality of the contributions in these later years has been distinctly in advance of those preceding them; whilst the illustrations have increased very greatly both in numbers and excellence. Our friends the subscribers, too, have helped the Magazine with their kindly and necessary support, and if they will only continue, like our contributors, to increase in numbers its future happiness and success will be assured.

Letter from the Rev. Osmond Fisher, M.A., F.G.S., Hon. Fellow and late Tutor of Jesus College, Cambridge (æt. 97).

DEAR DR. WOODWARD,—I well remember meeting you at the rooms of the Geological Society, then at Somerset House, when you told me that you proposed to bring out a periodical in the science, and you asked me to contribute papers to it; I took this as a great compliment, and I think I may feel proud that none of my contributions to the GEOLOGICAL MAGAZINE have ever been refused admission.[2] You are

[1] See GEOL. MAG., January to April, 1904.

[2] Mr. Fisher's contributions to the GEOLOGICAL MAGAZINE number 109. His life and portrait appeared in the February number for 1900, p. 49.

to be congratulated that your scheme has been eminently successful, having now obtained the fiftieth year of honourable fulfilment. I look upon the "forty years' index" which you and Mrs. Woodward brought out in July, 1905, as a marvel of correctness and arrangement, making the series of volumes it covers—which I have had bound—serviceable for reference. May you long have health and strength to continue the editorship. Believe me, yours sincerely,

OSMOND FISHER.

GRAVELEY, HUNTINGDON.
May 11, 1914.

From Sir Archibald Geikie, O.M., K.C.B., P.Pres.R.S., D.C.L., LL.D., F.G.S., etc.

There can surely be but one opinion among geologists all over the world, that their favourite science lies under no small obligation for the constant support which, during half a century, it has received from the GEOLOGICAL MAGAZINE. At the start of this journal there were some critics who predicted that it would soon become extinct, for the portion of the public specially interested in geological science was believed to be too limited to sustain its circulation, even were the progress of observation and discovery ample enough to furnish a supply of material for its pages. How completely this pessimistic foreboding has been falsified, the issue of the 600th number of the Magazine abundantly testifies.

That there have been times of difficulty in the path of the Editor, and how successfully he emerged from them, is known to many of his well-wishers. To his energy, industry, and tact, his own personal scientific standing, his friendly relations with the workers in every branch of geological science, and his readiness to open his pages to every serious contribution which these workers might send him, the GEOLOGICAL MAGAZINE owes the unbroken continuity of its monthly appearance and the high character which it has maintained as a scientific periodical.

Dr. Henry Woodward well deserves unstinted congratulations and thanks from all students of geology. The service which his journal has rendered to the progress of every department of the science is difficult to estimate, but no serious reader of its pages can doubt that this service has been real and has been continuous from the very first. As one of the contributors to the first number of the Magazine and one who has been familiar with its contents ever since,[1] I am glad of this opportunity to record my own sense of the great usefulness of the journal, and my admiration of the skill and success with which he has guided its career through fifty eventful years.

ARCHIBALD GEIKIE.

ATHENÆUM CLUB.
May 11, 1914.

[1] Sir A. Geikie has made nearly fifty contributions to its pages, and his life appeared in the GEOL. MAG. for 1890, p. 49, and a portrait on the centenary of the Geological Society, see GEOL. MAG., January, 1907, p. 1, Pl. I.

From Professor W. Boyd Dawkins, M.A., D.Sc. (Oxon.), D.Sc. (Manch.), F.R.S., F.S.A., F.G.S., etc., etc.

My dear Woodward,—I write to congratulate you on the fiftieth anniversary of the Geological Magazine, and on your unique experience as founder and editor from the very beginning. I do not know another case in the history of science of so long and so successful a tenure of a like position.

As one of the four contributors to its first number now alive, and the writer of many articles in the Magazine during the past fifty years,[1] I wish to convey to you my sense of personal obligation for innumerable kind acts and wise counsels in my relation to you as Editor. The Magazine itself has had an important share in the spreading of geological knowledge. Its leading features have been fearlessness and independence, and absolute freedom from subservience to popular opinion, or to the influence of cliques or bureaux. It has maintained always a high level of excellence, and been supported by the leaders of geological thought of their day.

In the future, when you hand over the Editor's chair to your successor, you will have the joy of knowing that the Magazine will be carried on, as before, on your lines, through the eminent men who form the Committee,[2] and that your work will live. With all good wishes, I am, my dear Woodward, yours truly,

W. Boyd Dawkins.

The Athenæum Club, Pall Mall.
May 13, 1914.

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

Dear Dr. Woodward,— . . . The work of Editor of the Geological Magazine for fifty years has reflected the greatest credit on your ability and extreme care of detail and accuracy in that rather delicate capacity, and I consider it is owing largely to these qualities that the Magazine has survived to the present day. I am surprised at what you say as regards the number of my own contributions,[3] and I certainly owe a debt of gratitude to the Geological Magazine, as, on more than one occasion, it has afforded a refuge for papers of my own intended for publication elsewhere.—Ever very truly yours,

Edward Hull.

14 Stanley Gardens, W.
May 11, 1914.

[1] Professor Boyd Dawkins has contributed forty articles to the Geological Magazine. His life and portrait appeared in the Geol. Mag., December, 1909, p. 529, Pl. XXX.

[2] The writer refers to the Editor's supporters whose names appear on the cover and on the title-page, namely: Professor J. W. Gregory, D.Sc., F.R.S., F.G.S.; Dr. George J. Hinde, F.R.S., F.G.S.; Sir Thomas Holland, K.C.I.E., A.R.C.S., D.Sc., F.R.S., F.G.S.; Dr. John Edward Marr, M.A., Sc.D. (Camb.), F.R.S., F.G.S.; Dr. J. J. H. Teall, M.A., Sc.D. (Camb.), LL.D., F.R.S., F.G.S.; Professor W. W. Watts, Sc.D., M.Sc., F.R.S., V.P.G.S.; Dr. Arthur Smith Woodward, F.R.S., F.L.S., Pres. Geol. Soc.

[3] Professor Hull has made 119 communications to the Geological Magazine between 1864 and 1914.

It may interest our readers to learn the record of the early efforts to provide an independent periodical publication for geologists in London.

1. In 1842 Mr. Charles Moxon published the *Geologist*, 8vo, two volumes (commencing January 1, 1842, ending in 1843). "A monthly record of Investigations and Discoveries in Geology, Mineralogy, and their Associate Sciences."

2. In 1846 Mr. Edward Charlesworth published the *London Geological Journal and Record of Discoveries in British and Foreign Palæontology*, three numbers, royal 8vo, London, 1846–7.

3. In 1858 Mr. S. J. Mackie commenced to publish the *Geologist*, a monthly journal of geology, which extended to June, 1864, seven volumes, when it was purchased by Longmans and incorporated in the title of the GEOLOGICAL MAGAZINE.

4. In 1865 Mr. S. J. Mackie issued a *Geological and Natural History Repertory*, which appeared periodically until 1869.

5. The GEOLOGICAL MAGAZINE, a monthly journal of geology, with which is incorporated the *Geologist*. (1) Edited by T. Rupert Jones and Henry Woodward, the first twelve numbers, July, 1864, to June, 1865; (2) from June to December, 1865, by Henry Woodward, assisted by Professor John Morris and Robert Etheridge, 1865–85; (3) from 1885, by Henry Woodward, R. Etheridge, W. H. Hudleston, and Dr. G. J. Hinde; (4) from 1895 the name of Horace B. Woodward was added to the above; (5) from 1909 Henry Woodward was assisted by Professor J. W. Gregory, Dr. Hinde, Sir Thomas Holland, Professor W. W. Watts, Dr. Arthur Smith Woodward, and Horace B. Woodward; (6) in 1914 the name of Horace B. Woodward was removed by death[1] and the names of Dr. John E. Marr and Dr. J. J. H. Teall were added to those of 1909.

HENRY WOODWARD.

I.—ON SOME INCLUSIONS IN THE GREAT WHIN SILL OF NORTHUMBERLAND.

By JOHN ARMSTRONG SMYTHE, Ph.D., D.Sc.

(PLATE XVII.)

THE inclusions to be described in this paper occur in the Whin Sill at Snook Point on the coast of Northumberland. This is the most northerly exposure of the whin in the coast-section which stretches from Cullernose Point, through Dunstanburgh, to Beadnell Sands; and it is here that the outcrop leaves the coast and sweeps out to sea, to reappear further north in the Farne Islands and, on the mainland, at Bamburgh.

The exposure at Snook Point is a thin sill, one of two into which the whin seems to be split in this neighbourhood. It occupies the foreshore in the form of a triangular patch, about 70 yards broad at the shore-end, from the apex of which a spur is sent out to sea, in an easterly direction, for several hundred yards. The dip is south at a gentle angle, and the whin rests on sandstone and is overlain by limestone (the Great), both contacts being metamorphosed. The

[1] See Obituary, GEOL. MAG., March, 1914, p. 142, with a Portrait.

thickness of the sill is only about 25 feet; the lower 15 feet is massive, with a tendency to columnar structure, the rock free from amygdules, coarse and breakable with equal ease in all directions. Above this the rock is bedded, amygdaloidal, finer in grain, and weathers in lumpy form. The topmost bed, however, in contact with the limestone, is free from amygdules, very fine in grain, vertically jointed, weathers into sharp, jagged points, and splinters under the hammer.

Near the middle of the triangular patch, high up among the bedded whin and just by the pool which is left at low tide, the rock takes on a dyke-like aspect, is well jointed in directions east and west and north and south, and breaks most readily along vertical planes. The apparent dyke is about 6 feet wide and it runs east and west, that is, parallel to the strike of the whin. In one place it forms an outstanding feature several feet high, but it cannot be traced far, as it seems to merge into the surrounding sheet.

The inclusions were first discovered in this dyke-like rock. The whole exposure of whin yielded, on systematic examination, about two hundred specimens, and the range of these was found to be restricted to the dyke-like mass and the bed of trap with which it appears to coalesce. The maximum dimensions of the rock with inclusions are about 90 by 20 feet, and by far the greater number of inclusions were found near the longer axis of this tract, which coincides with the 'dyke' and its prolongation.

The size of the inclusions varies from $\frac{1}{8}$ to $\frac{7}{8}$ in., but is usually about $\frac{3}{8}$ in., the same as that of the ordinary amygdules. They are characterized by a large number of facets, coated with a thin film of a mineral having a bronze-yellow or, occasionally, a reddish colour. When this film is chipped off a bright, reflecting plane surface is revealed, and similar surfaces line the whin in which the inclusions are embedded, the relations being similar to that of a mould and its cast. These surfaces and films constitute planes of weakness, and thus it happens that on breaking the rock a many-faced cast or knob and its mould are simultaneously disclosed; and, as the film clings most tenaciously to the knob, this generally has a bronze colour, while the mould is white and glassy. Occasionally the reverse is the case, the film lining the mould; and, again, patches of the film may be retained by both knob and mould, the bronze areas on the one corresponding to the white highly reflecting areas on the other.

It happens comparatively rarely that a knob is broken across; in such cases the inside usually appears to the naked eye to consist of ordinary whin; but at times, especially in weathered specimens, a difference is discernible, the rock being darker, finer-grained, and more easily scratched with a knife. When finely ground the powder from the inclusions has a dark-grey colour, that of the whin being somewhat brownish. On rare occasions weathered specimens show a general spherical form, and it may be remarked, in anticipation, that a corresponding circular outline is exhibited by the thin sections. Only one hemisphere, however, shows the multitudinous reflecting surfaces which are so characteristic of these inclusions. A completely facetted inclusion has never been secured, either by accident or design, and this observation has been confirmed by the experience gained in grinding the thin sections. In the fresh rocks there is no plane of weakness between the unfacetted portion of an inclusion and the surrounding normal whin, so that the spherical shape of the former is not displayed.

Another curious observation is deserving of mention. When the field-work was about half completed the general impression had been gained that the moulds of the inclusions, exposed by the breaking of the whin, faced upwards. Special attention was afterwards paid to this point and the impression was completely confirmed.

Thus one may say with considerable probability that the inclusions, spherical in a general way, are, in their natural position, only facetted on the lower hemisphere.

Detailed Description of the Inclusions.

Observations made on the collected material will now be considered in detail, and attention will be directed to some characteristics of the inclusions as defined by the facets. The normal aspect of these is that of a hemisphere round which the facets are arranged tangentially. Deviations from this type are, however, not uncommon. In a few cases two inclusions are joined by a narrow facetted ridge. Some individuals are collapsed in the middle; less frequently they appear crushed and flattened, the facets being irregularly, though locally, dispersed through the rock, and a few specimens show one inclusion within another.

The facets vary in number and size without regularity, some specimens having as many as fifty. These are often circular, or rudely so, and the contact is imperfect, non-reflecting basalt occupying the spaces and coigns between them (Pl. XVII, Fig. 1). At times the shape is rudely pentagonal or hexagonal, or irregularly polygonal, and in these cases the junction of contiguous facets is frequently a perfectly straight line.

The most striking character of the facets, however, is their crystalline structure, occasionally visible with a hand-lens, but usually requiring observation through a microscope. This phase of the subject has been studied in some detail, and many of the most pronounced features have been photographed in reflected light, using both oblique and vertical illumination. For photographic purposes oblique illumination is somewhat unsatisfactory, as it is almost impossible to use high powers and to get much of the field in focus. These difficulties do not beset the operations when vertical illumination is employed. Nevertheless, for purposes of observation only, the former method is greatly to be preferred.

For convenience of description the observations will be classified as appertaining to the clear, glassy-looking surfaces of the *knobs* and *moulds*[1] (white, blue, or slightly bronze in colour, according to the incidence of the light) and the thin *film* of pronounced bronze colour which separates these surfaces.

[1] The term 'mould' is used in this connexion without any implication that the knob has taken its shape from the mould. The observations, in fact, rather point to the contrary.

The *knob*-facets are characterized by a complex, crystalline structure, sometimes appearing like striation, readily visible under low powers ($\frac{4}{10}$ in. objective), occasionally even with a hand-lens. When well developed this structure seems to be that of a network of felspar crystals, the ends of which, at times, make up the edge of the facet, which has a serrated outline in consequence. On a more minute scale the appearance is that of striation, but this is resolved under higher powers into a crystalline growth similar to the former one, the apparent striation being produced by bundles of parallel, close-fitting shafts. Some surfaces are structureless in parts, others completely crystallized, and the orientation of the crystals varies in different parts of the same facet; a common feature, too, is the intergrowth of two parallel bundles of crystals. The appearances, in general, are very similar to those produced in the laboratory by the crystallization of thin films of material on a flat surface, or between two glass plates.

Some specimens are traversed by wavy cracks from which the crystal-shafts spring, or against which their tooth-shaped ends abut, and when, as sometimes happens, these cracks are curved, they usually enclose a crystallization distinct in direction from the surrounding mass (Pl. XVII, Fig. 2).

The lines of apparent striation can often be resolved, under high powers, into dark, aligned dots, which undoubtedly represent basic matter eliminated in a liquid condition along the sides of the shafts during their crystallization (Pl. XVII, Fig. 6).

When several facets meet with sharp boundaries they are occasionally crossed by bands of crystalline growth, the orientation of which is not altered in passing from one facet to another.

The great complexity and beauty of many of these structural peculiarities will be better realized by reference to the photographs (Plate XVII).

The facets of the *moulds* resemble in detail those of the knobs, but, in addition, they frequently exhibit dark, rectangular and rhomboidal markings or impressions, only one example of which has been met with on the knobs. Sometimes a single facet will show half a dozen such impressions, or again the line of intersection of two facets will cut through one or more (even three) of them, each facet thus claiming part of the impression. The edges of the impressions are frayed at times somewhat in the manner of a skeleton-crystal, and, in one case, the crystalline material enveloping the frayed edges perfects the crude outline of the impression (Pl. XVII, Figs. 1, 3).

These appearances seem to indicate that the impressions are in the nature of negative crystals, produced by local dearth of crystalline material, owing to the contact of the film with the surrounding basalt. Where the contact is imperfect the small amount of intervening crystallizable matter allows of the production of a skeleton-crystal, and the combination of skeletal and negative crystal gives the frayed-edge effect. The comparative absence of rhomboidal impressions on the knobs and their frequent occurrence on the moulds is accounted for by the fact, established by the study of the thin sections, that the knobs (the inclusions proper) consist in great part of felspar, the crystallization of which in contact with the films is evidently the cause of the surface structures of their facets, while but little felspar usually separates the films from the surrounding whin, so that actual contact is at times inevitable.

The thickness of the crystalline coating of both knobs and moulds is very slight; in fact, the crystallization-phenomena seem to be merely a surface-effect. Scrapings of the coatings appear, by examination in polarized light, to consist of the same felspathic material which is the prime constituent of the inclusions.

The *films*, which part the knob-surfaces and the moulds, have a bronze-yellow, rarely pyritic coloration, becoming olive-green in certain lights. They can be easily scaled off either knob or mould; their thickness is about that of ordinary writing-paper; they are opaque, sink in Sonstadt solution of specific gravity 3·1, are strongly attracted by a bar magnet, and, in fact, show marked polarity.

Both surfaces of the films show crystalline structure, though without correspondence in grouping and orientation, and a similar lack of correspondence exists between the structure of the film-surfaces and those of knob or mould in contact with them. The crystalline markings differ somewhat from those described above, taking the form rather of narrow ridges or troughs, grouped in parallel lines or tufty aggregates, sometimes on either side of an axis (Pl. XVII, Fig. 5).

Minute plates of reflecting mineral found, not infrequently, within inclusions usually exhibit the same structures as the films.

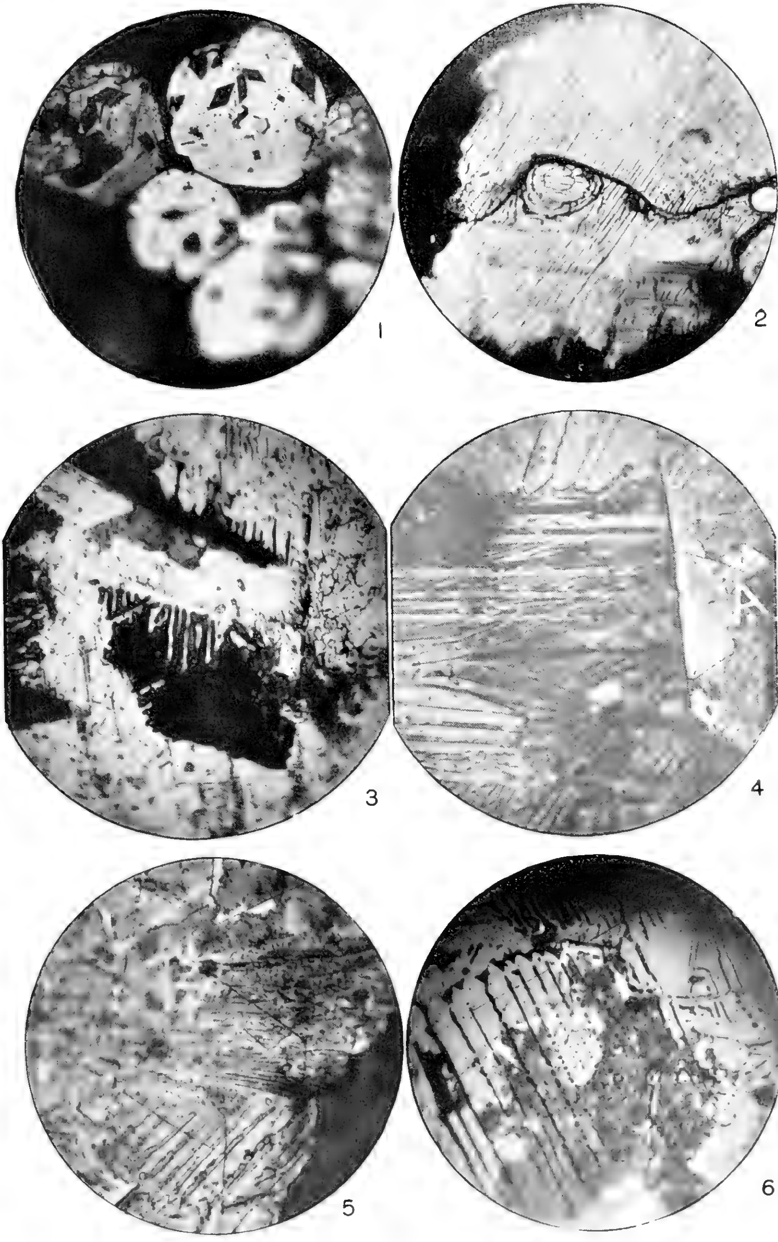
When fragments of the films are digested in warm, fairly concentrated hydrochloric acid they quickly dissolve. The residual powder is non-magnetic, the solution contains ferrous iron and titanium, and the gases evolved respond readily to the tests for hydrogen sulphide. These observations were confirmed on a complete small inclusion; after short immersion in the acid the film was dissolved, disclosing the knob-facets, characteristically marked. Microscopic examination of the films shows them to be sometimes composite, but the above reactions prove that the bronze-coloured mineral is pyrrhotite. It is difficult to say whether the magnetic properties of the films are due only to this mineral or partly to admixture with magnetite, but it is significant that the films in one specimen, which had a pronounced pyritic colour, were devoid of magnetic properties.

The Petrology of the Inclusions.

Thin sections show very considerable differences between the inclusions and the surrounding whin. The latter is normal in character, and the inclusions differ from it, broadly speaking, in being much finer in grain, in the comparative absence of augite, and the presence of a large amount of felspathic material and some quartz.

Of the mineral constituents, felspar greatly predominates, and oxides of iron appear more plentiful, as a rule, than in the normal whin, despite the smaller yield on analysis. This is to be explained by the rarity of augite, nearly all the iron being visible in the form of opaque minerals.

The felspar exists in two forms; in groups of well-crystallized individuals, like those in the normal whin, though at times with the



Microphotographs of surfaces of inclusions from the Great Whin Sill of Northumberland.

twinning less developed; and as patches showing spherulitic structure. These spherulites have a brownish tinge and form a highly characteristic component of the inclusions. They have been the last material to consolidate, they are often gathered round a cluster of felspar crystals, or a single individual, and they sometimes show a tendency to assume the outlines of a felspar crystal.

Quartz is a common constituent of the inclusions, and occurs both in interstitial and idiomorphic forms; it is most abundant at the edges of the spherulites and is often penetrated by felspar. There are several opaque iron-minerals present. One has a bronze colour and occurs in roundish plates and long slender bands; another is bluish-black and occasionally shows, in reflected light, a structure like that of the films. Sections cut vertically through the films often show these two minerals, side by side, sometimes fringed with a third, dull, non-reflecting mineral; and when the section makes a low angle with the film the dull mineral is seen to be entirely in the skeletal condition. The films are thus sometimes composite, and appear to consist of pyrrhotite and magnetite, possibly with a little titaniferous oxide, and these minerals also occur irregularly distributed throughout the inclusions. In addition to these some of the slides also show a few scattered crystals of ilmenite which exhibit the characteristic cinnamon-brown colour.

Apatite is the only accessory mineral identified with certainty. It occurs, with moderate frequency, in well-developed crystals with dark centres, and also in the form of bundles of long, but exceedingly slender, needles. These are very abundant in all the sections, and undoubtedly contribute greatly to the high phosphorus-content established by analysis. They penetrate all the other constituents except the iron-minerals.

Most of the slides show small amygdules, fringed with iron-oxide and filled with secondary quartz and calcite. This confirms the observations made on hand-specimens as to the frequency of occurrence of amygdules in the inclusions. Another observation, mentioned above, concerning the contact of the films, finds support from the study of the sections; for it is found that adjacent films sometimes meet at a sharp angle, and are sometimes separated for some little distance, the intervening space being occupied by the materials peculiar to the inclusions.

With respect to the relations between the inclusions and the surrounding basalt, the study of the slices yields some rather unexpected results. Though the petrological contrast of the rocks is considerable, the contact is never clearly marked. The general shape of the inclusions in the sections is circular, but the edges are somewhat wavy in outline, owing to interpenetration of the components of each rock-species. Generally speaking, it may be stated that the lower the magnification the better is the definition of the inclusions.

Again, though in hand-specimens half of an inclusion is quite sharply defined by the films, the latter never constitute boundaries in the sections; there is practically always some felspathic material on the outside of the films, even though the thickness of this is, at times, slight. This is clearly the material which gives the crystallization-phenomena of the mould-surfaces.

The occurrence of concentric inclusions, noted above, is borne out by the sections. In one prominent example the inner inclusion is largely made up of spherulites, while the material of the enveloping inclusion is of greater variety and shows a more advanced stage of crystallization.

Mention may be made here of some smooth, roundish masses which occur along with the inclusions, and differ from them externally in the absence of bright facets and films and by a slight, but distinct, surface-sheen. Sections of these have all the characters of the inclusions proper, and, in some cases, actually enclose them. Though distributed sparingly, they evidently belong to the same order of phenomena as the inclusions.

The Chemistry of the Rocks.

For the purposes of chemical examination several inclusions, or, more accurately, their facetted hemispheres, were isolated as completely as possible, and a fairly large sample of the whin immediately surrounding them was also taken. Both samples were coarsely crushed, sieved free from dust, then ground and dried at 110° C. Total iron in each case is reckoned as ferrous oxide. The analytical data are given below in columns I and II, those for the whin being the mean values of closely-agreeing duplicates. Some other analyses (in which the iron is recalculated as ferrous oxide) are given in the table (columns III, IV, and V) for the sake of comparison; they will be dealt with later.

	I.	II.	III.	IV.	V.
SiO_2 . .	49·54	58·10	61·18	58·29	57·80
Al_2O_3 . .	16·64	14·49	19·95	14·74	16·18
TiO_2 . .	2·84	1·65	—	—	—
FeO . .	11·44	9·51	3·20	9·36	9·00
MnO . .	0·20	0·16	—	0·27	—
CaO . .	9·00	5·05	5·45	6·93	6·18
MgO . .	5·51	3·32	0·92	4·17	4·68
K_2O . .	0·97	2·36	2·83	1·53	0·77
Na_2O . .	2·33	2·76	4·70	2·71	2·38
P_2O_5 . .	0·28	0·73	—	—	—
CO_2 . .	0·16	{1·61	{1·13	0·30	{1·70
H_2O . .	0·47			1·35	
	99·38	99·74			
S.G. . .	2·900	2·725	2·67–2·70	2·770	2·810

I. Whin Sill surrounding inclusions, Snook Point.
II. Inclusions, Snook Point.
III. Felspars from Whin Sill, Caldron Snout (analysis by Teall).
IV. Cleveland Dyke (mean of three analyses by Stead and Stock).
V. Acklington Dyke (analysis by Stead).

The figures for the rock surrounding the inclusions (No. I) agree very closely with Teall's analyses of the Whin Sill from Borcovicus and Caldron Snout,[1] and they afford fresh evidence of the uniformity

[1] Quart. Journ. Geol. Soc., vol. xl, p. 654, 1884.

in composition of that great mass of intrusive rock; in addition they show that the peculiarities of the inclusions are not due to local variation in the sill as a whole.

Comparing the analyses I and II, it will be seen that silica and the alkalies have increased in the inclusions at the expense of iron, lime, and magnesia, and of the alkalies, potash has increased to a greater extent than soda. The relations between the whin and the inclusions are thus precisely those which have been proved to exist in rocks of andesitic composition between the rock as a whole and its glassy base or groundmass.[1]

This relationship points to a genetic connexion between the rocks. Assuming for the moment that such exists, then the decrease in iron is much smaller than has been usually observed. Such differences may, however, be expected, since the Whin Sill is more basic than the rocks which have been studied in this light, and there is possibly some difference in the order of crystallization in the two cases.

From the simultaneous decrease in titanium and iron it might be inferred that the former is present, to some extent at least, as ilmenite, as proved by Teall in the rock of Caldron Snout; but as the decrease is not by any means proportionate, and as augite is rare in the inclusions, it would appear that some of the titanium in the whin was included in the augite.

The distribution of phosphorus, in cases such as those we are dealing with, is a question to which but little attention has been paid, though it is one of some interest owing to the position of apatite in the order of crystallization of minerals from magmas. The analyses show a very considerable enrichment in phosphorus in the inclusions. Assuming the phosphorus in the rocks to be present as chlorapatite, then the whin contains 0·68 per cent and the inclusions 1·78 per cent of that mineral. The inclusions thus contain 2·6 times as much apatite as the whin, though one might expect the order to be reversed corresponding to the greater acidity of the inclusions.

There is a general resemblance in composition between the felspars isolated from the Whin Sill by Teall (see column III) and the inclusions, the chief difference being in the iron. If we imagine the felspars mixed with 7 per cent of iron oxide, then the resulting material would be very similar in composition to the inclusions. It may be noted, too, that the ratio of the oxides $(Na_2, K_2)O : CaO$ in the inclusions (1 : 1·3) is not far different from that in the felspars (1 : 1).

Before leaving the discussion of the analyses it may be pointed out that while the Whin Sill resembles in composition the dykes of Hett, Collywell, Crookdene, and Morpeth, the inclusions are very similar in composition to the Cleveland and Acklington dykes, as may be seen by comparison of columns II, IV, and V in the table above. There are indications here of an association analogous to that observed in Skye, where dykes of augite-andesite, similar in composition to the Acklington and Cleveland dykes, frequently

[1] See J. J. H. Teall, *British Petrography*, 1888, pp. 42, 43, also, among others, J. W. Judd, Q.J.G.S., 1890, p. 341; 1893, p. 536; and A. Harker, *The Tertiary Igneous Rocks of Skye*, 1904, pp. 331, 339.

contain vesicles and kernels of thoroughly acidic composition, and are associated in the same area with dykes of acidic pitchstone.[1]

The Origin of the Inclusions.

The observations described in the foregoing pages throw some light on the origin of the inclusions, though many of the deductions are necessarily of a somewhat speculative nature, and some of the difficulties are probably incapable of solution by the data at present available. The three main aspects of the problem are: how was the material of the inclusions generated, how did it get into its present position, and by what process did the inclusions acquire their form and characteristic facetting?

With regard to the first point, there is nothing to indicate that the inclusions represent foreign material, igneous or sedimentary, which has been caught up by the whin during intrusion; and the evidence, both chemical and petrological, makes it clear that local variation of the whin as a whole is not at the root of the matter. In the lack of definition, or of sharp contact between the inclusions and the surrounding rock, and in the absence of tangentially-arranged felspars around them, the inclusions differ from the glass-filled amygdules of many of the local dykes,[2] and thus their material cannot be regarded as a differentiation-product of the whin, produced in situ by the process of crystallization, and concentrated locally by injection into amygdaloidal cavities.

That the material has been derived from the whin, however, by some process of fractionation seems evident from its associations, its likeness in composition to the felspars, which are the early crystallization-products from that magma, and especially by the chemical relationship it bears to that rock.

In view of these considerations and also of the field-relationships, the lower specific gravity of the inclusions, and the very frequent occurrence in them of amygdaloidal cavities, it seems inevitable to conclude that the material of the inclusions is derived from the whin and has floated upwards into its present position from its source below.

Now at this place the whin forms a comparatively thin sill, so that one must further assume the sill to be connected with a deep-seated source of supply. The suggestion is thus made that the Whin Sill at Snook Point is directly connected with a feeder of some sort; that the sill itself is composite in the sense that several successive injections of magma have taken place; and that after the final injection, and before its consolidation, small masses of magma, specifically lighter, of different composition, and possibly buoyed up by gas-bubbles, floated up the feeder and became entrapped in the viscous basalt of the last-injected sheet, in the immediate neighbourhood of the feeder, and in the feeder itself.

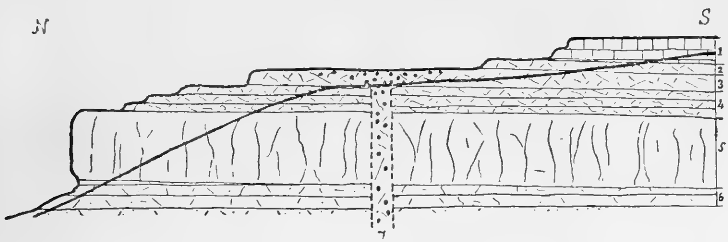
This hypothesis accounts satisfactorily for many peculiarities in the mode of occurrence of the inclusions, as, for example, their restricted range to the dyke-like portion of the rock and the sheet

[1] A. Harker, *The Tertiary Igneous Rocks of Skye*, 1904, p. 402.
[2] J. J. H. Teall, Geol. Mag., Dec. III, Vol. VI, p. 481, 1899. M. K. Heslop & J. A. Smythe, Q.J.G.S., vol. lxvi, p. 1, 1910.

with which this appears to blend, the numbers being greatest immediately over the feeder, and falling off on either side of it (Figure). The general spherical character of the inclusions and the lack of sharp boundaries between them and the surrounding rock are explicable as the results of two opposing tendencies—surface-tension, promoting a spherical drop-like form, and diffusion, tending to the blending of the magmas and the establishment of uniform composition.

There are two questions arising out of the hypothesis which require consideration; the first is relative to the feeders of the Whin Sill, the second concerns the differentiation-process.

With regard to the first there appears to be no positive evidence. Thus Professor Lebour and his collaborators write: "Up to the present time no whin dyke has ever been proved to belong to, cut through, or come in contact with, the Great Whin Sill."[1] And again: "The relation which the whin dykes of the district bear to the Whin Sill is an interesting question; but it is one upon which little can be said. There is no certain case in Northumberland of



SECTION AT SNOOK POINT.

Illustrating disposition of Whin Sill and inclusions and the hypothetical dyke-feeder. (Below the heavy continuous line the section is diagrammatic; the portion which can be observed lies above this line.)

1. Great Limestone.

Whin Sill, about 25 feet thick:

2. Fine-grained whin, without amygdules, altered at contact with limestone.
3. Bedded whin, with amygdules and inclusions.
4. Bedded whin, with amygdules.
5. Columnar whin, altered at contact with sedimentary beds.

6. Carboniferous sandstone.
7. Hypothetical dyke-feeder of whin, containing inclusions (black dots).

a whin dyke intersecting the Whin Sill."[2] So far as the writer is aware these words adequately express the state of our knowledge on the subject at the present day; visual proof of connexion at Snook Point is not to be expected, owing to the limited exposure on the foreshore and the thick cover of blown sand on the adjacent land.

With respect to the differentiation-process, it would appear that

[1] G. A. Lebour & Mark Fryer, "On the Harkess Rocks, near Bamburgh": North of England Institute of Mining and Mechanical Engineers, vol. xxvi, p. 1, 1877.

[2] W. Topley & G. A. Lebour, "On the Intrusive Character of the Whin Sill of Northumberland": Q.J.G.S., vol. xxxiii, p. 406, 1877.

the inclusions represent a primary crystallization of the magma, consisting, as they do, so largely of felspar, closely allied in composition to that of the Whin Sill (from which it is the first mineral to crystallize in quantity), and abounding in apatite, one of the earliest of the minerals to separate from the magma. This case, therefore, resembles in some degree that whereby the anorthite inclusions of the Crookdene group of local dykes were formed.[1] Both are products of early crystallization, but whereas the anorthite in the dykes crystallized under plutonic conditions and was floated up in a solid state, the inclusions evidently came into position in a liquid form, or at most with the iron minerals consolidated. Differentiation in the latter case has thus been effected either in the liquid magma, or an early solid product of the process has been remelted owing to some change in condition.

The interpretation of the salient characteristics of the inclusions, viz. the facetting and crystallization-phenomena, presents many difficulties and uncertainties. The beautifully marked surfaces are clearly the result of the crystallization of material, mainly felspathic, in contact with the plane surfaces of the films, and the proof from the thin sections that this material lies on both sides of the film explains the similarity in appearance of both knobs and moulds. The corollary to this view is that the pseudo-crystal form of the inclusions is determined by the arrangement of the film-plates in a liquid medium.

If full credit be given to observations made in the field and laboratory, that only the lower hemisphere of an inclusion in its natural position is facetted, then one of the formative factors would appear to be the settling, under gravity, of the heavy already fashioned films of iron minerals in a molten matrix. The only other recognizable directive force which may have been operative in arranging the plates is magnetic; for, as already stated, the films show well-defined magnetic polarity and when suspended in a slightly denser liquid would slowly sink and arrange themselves end on end. Such a process might be helped by the crystallization of the apatite, the crystals of which, forming a kind of network, would help to keep the shell of films near the boundaries of the inclusion. However produced, such fragile structures would be very unstable, and the slightest movement in the rock would cause their collapse, malformation, or even obliteration.

All of these effects can be noted in the specimens and thus add support to the view, though the difficulties in the way of its acceptance are so great that the suggestion must be regarded only as a crude working hypothesis, which may possibly serve its purpose in the elucidation of the prime difficulty—the origin of the mock-crystal structure of the inclusions.

In conclusion, the author wishes to express his cordial thanks to Professor Lebour for his encouragement and interest in this work, and to W. M. Hutchings, Esq., for his valuable help in the examination of the rock sections.

[1] M. K. Heslop & J. A. Smythe, "The Dyke at Crookdene," etc.: Q.J.G.S., vol. lxvi, p. 1, 1910.

EXPLANATION OF PLATE XVII.

The six microphotographs reproduced in this Plate are taken by *reflected* light, and illustrate the crystallization-phenomena of the plane surfaces or facets which bound the inclusions.

FIG. 1. Group of roundish mould-facets showing rhomboidal impressions. Oblique illumination, magnified 8 diameters.
,, 2. Knob-facet, with curved cracks and pseudo-striation. Oblique illumination, magnified 22 diameters.
,, 3. Mould-facet, with highly magnified, rhomboidal impression showing frayed edge. The perfecting of the outline of the impression in the enveloping crystalline material can be faintly seen, as shown by the white crosses.
,, 4. Knob-facet showing crystalline structure. A fragment of film is marked A.
,, 5. Structure of film, a portion of which is shown in Fig. 4 (marked A).
,, 6. Knob-facet showing crystal-shafts and resolution of pseudo-striation into aligned dots.

Figs. 3–6, vertical illumination, magnified 110 diameters.

II.—The Foraminifera of the Speeton Clay of Yorkshire.

By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S.

(PLATES XVIII AND XIX.)[1]

(*Continued from the May Number, p. 222.*)

Family LAGENIDÆ.

Sub-family LAGENINÆ.

Lagena, Walker & Boys.

Lagena globosa (Montagu). (Pl. XVIII, Fig. 6.)

Vermiculum globosum, Montagu, 1803: Test. Brit., p. 523.
Entosolenia globosa, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 318, pl. i, figs. 1–3.
Lagena globosa, Burrows, Sherborn, & Bailey, 1890: Journ. Roy. Micr. Soc., p. 555, pl. ix, figs. 1, 2, 4.

Remarks.—This species has been recorded in rocks as old as the Wenlock Limestone and shale (Brady), and is still living in almost every depth of water and in all latitudes.

Horizon.—Present in C_1, C_2, C_{10}. One specimen from each bed.

Lagena apiculata, Reuss. (Pl. XVIII, Fig. 12.)

Lagena apiculata, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 319, pl. i, figs. 4–8, 10, 11.

Remarks.—*L. apiculata* is known from various formations from the Lias to the Recent. It is still abundant in both shallow and deep water. It is noteworthy that the specimens from C_1 and C_{10} are very large (see Pl. XVIII, Fig. 12).

Horizon.—Found in B base *c*, C_1, ? C_9 (broken specimen), C_{10}. One from each horizon.

[1] Plate XIX will appear in the July Number with the concluding part of the author's paper.

Lagena apiculata, var. *danfordi*, var. nov. (Pl. XVIII, Fig. 8.)

Test elongated, pointed at both ends, slightly oviform in cross-section. The narrower side is straight, the wider curving towards it at the ends. The base tapers rapidly to a point, the oral end is bluntly pointed. Length about ·475 mm. (·018 in.), greatest diameter ·095 mm. (·0037 in.). It resembles most nearly the figure of *L. apiculata* in Burrows, Sherborn, & Bailey's paper on the Red Chalk (pl. ix, fig. 6), but the three specimens found all agree in having both ends of the test in the same straight edge. The variety has been named after Mr. C. G. Danford, to whom, as already mentioned, I am indebted for the specimens of Speeton Clay which I have examined.

Horizon.—Found in Upper C_2. Three specimens.

Lagena lævis (Montagu). (Pl. XVIII, Fig. 14.)

Vermiculum læve, Montagu, 1803: Test. Brit., p. 524.
Lagena lævis, Brady, 1884: Chall. Rep., vol. ix, p. 455, pl. lvi, figs. 7–14, 30.
L. lævis, Burrows, Sherborn, & Bailey, 1890: Journ. Roy. Micr. Soc., p. 555, pl. ix, fig. 3.

Remarks.—This is probably the commonest and most widely distributed of the *Lagenæ*, and has been recorded from the Woolhope Beds. At present it occurs at all depths down to at least 2,435 fathoms (Chall. Rep.).

Horizon.—Found in B base *c*. Several specimens.

Sub-family NODOSARIINÆ.

Nodosaria, Lamarck.

Sub-genera Glandulina and Dentalina, d'Orbigny.

Nodosaria (*G.*) *lævigata*, var. *strobilus*, Reuss. (Pl. XVIII, Fig. 11.)

Glandulina lævigata, var. *strobilus*, Reuss, 1870: Sitzungsb. d. k. Ak. Wiss. Wien, vol. lxii, p. 477; Schlicht, Foram. Pietzpuhl, 1870, pl. vi, figs. 15, 16.

Remarks.—The forms of *Nodosaria* are very variable, and the specimen found does not differ much from *N. mutabilis*, Reuss, figured in his paper on the Foraminifera of the Hils (pl. v, figs. 9–11). It is noteworthy that the earlier sutures are oblique, a condition regarded by Reuss as of generic importance when he founded the genus *Psecadium* (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xliv, p. 368, 1861). The variety has been recorded from the Tertiary Septaria-clay of Pietzpuhl.

Horizon.—One specimen only from C_{10}.

Nodosaria hispida, d'Orbigny. (Pl. XVIII, Fig. 18.)

Nodosaria hispida, d'Orbigny, 1846: For. Foss. Vien., p. 35, pl. i, figs. 24, 25.
N. conspurcata, Reuss, 1863: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlviii, p. 43, pl. ii, figs. 10–14.
N. hispida, Brady, 1884: Chall. Rep., vol. ix, p. 507, pl. lxiii, figs. 12–16.

Remarks.—The species is known from the Middle and Upper Lias of the West of England (Brady, Walford), the Chalk of Ireland

(Wright), the London Clay (Jones & Parker), the Tertiary Septaria-clays of Hermsdorf and Pietzpuhl (Reuss), etc., and was found by the *Challenger* Expedition at depths of from 95 to 450 fathoms.

Horizon.—One broken specimen from B base *b*.

Nodosaria calomorpha, Reuss. (Pl. XVIII, Fig. 16.)

Nodosaria calomorpha, Reuss, 1865: Denkschr. d. k. Ak. Wiss. Wien, vol. xxv, p. 129, pl. i, figs. 15–19.

N. (*Dentalina*) *consobrina*, Parker & Jones, 1865: Phil. Trans., vol. clv, p. 342, pl. xvi, fig. 3.

N. calomorpha, Terrigi, 1880: Atti dell'Accad. Pont., ann. xxxiii, p. 178, pl. i, fig. 7.

N. calomorpha, Brady, 1884: Chall. Rep., vol. ix, p. 497, pl. lxi, figs. 23–7.

Remarks.—One specimen found has three chambers, the others but two, and they differ in the relative width of the chambers, resembling in this respect the figures of Parker & Jones and Terrigi. The species has been described from Tertiary beds by Reuss and Terrigi, and is present in the Atlantic and Pacific Oceans at depths varying from 6 to 2,200 fathoms (Brady).

Horizon.—Found in B base *c*. Several specimens.

Nodosaria (*Dentalina*) *siliqua* (?), Reuss. (Pl. XVIII, Fig. 19.)

Dentalina siliqua, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 40, pl. ii, fig. 11.

Remarks.—A damaged specimen agrees rather closely with Reuss' figure, but the upper part is broken away. It has been recorded by Reuss from the highest bed of the German Hils and from the Pläner.

Horizon.—Found in B base *c*. One specimen.

Nodosaria (*Dentalina*) *fontannesi*, Berthelin. (Pl. XVIII, Fig. 7.)

Dentalina fontannesi, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 42, pl. ii, fig. 14.

N. (*D.*) *fontannesi*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 593, pl. ix, fig. 15.

Remarks.—The species is described from the Gault of France and Folkestone by Berthelin and Chapman respectively.

Horizon.—Found in Upper C_2. One specimen.

Nodosaria (*Dentalina*) *lorneiana*, d'Orbigny. (Pl. XVIII, Fig. 13.)

Dentalina lorneiana, d'Orbigny, 1840: Mém. Soc. géol. France, vol. iv, p. 14, pl. i, figs. 8, 9.

Nodosaria lorneiana, Reuss, 1845: Verstein. böhm. Kreideform., vol. i, p. 27, pl. viii, fig. 5.

N. (*D.*) *lorneiana*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 588, pl. viii, figs. 30, 31.

Remarks.—The species is recorded from the Folkestone Gault (Chapman), the Bohemian Cretaceous (Reuss), and the Lower Chalk of Dover (Jones). It seems probable that *N. nuda*, Reuss (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 38, pl. ii, figs. 8, 9, 1862), is the same species, and if so the form occurs in the Gault of North Germany.

Horizon.—Found in Upper C_2. Two specimens.

Nodosaria (*Dentalina*) *legumen*, Reuss. (Pl. XVIII, Fig. 22.)

Nodosaria (*Dentalina*) *legumen*, Reuss, 1845: Verstein. böhm. Kreideform., pt. i, p. 28, pl. xiii, figs. 23, 24.

D. legumen, Reuss, 1860: Sitzungsb. d. k. Ak. Wiss. Wien, p. 187, pl. iii, fig. 5.

Remarks.—This form has been recorded from the Gault of Folkestone (Chapman), of France (Berthelin), and the Rhine (Reuss), and from the Cretaceous of Bohemia and Hanover (Reuss). Brady (Chall. Rep., vol. ix, p. 504) considers it to be the same as *N. communis*, d'Orb., which has at present a worldwide range.

Horizon.—Found in B base *c*. One specimen.

Nodosaria (*Dentalina*) *communis*, d'Orbigny. (Pl. XVIII, Fig. 24.)

Nodosaria (*Dentalina*) *communis*, d'Orbigny, 1826: Ann. Sci. Nat., vol. vii, p. 254, No. 35.

N. (*D.*) *communis*, Brady, 1884: Chall. Rep., vol. ix, p. 504, pl. lxii, figs. 19–22.

N. (*D.*) *communis*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 590, pl. ix, fig. 1.

Remarks.—The species is known from many deposits above and below the Cretaceous System (Chapman). Its present distribution is worldwide, and it is found at almost any depth.

Horizon.—Found in Upper C_2. One specimen.

Nodosaria (*Dentalina*) *roemeri*, Neugeboren. (Pl. XVIII, Fig. 9.)

Dentalina roemeri, Neugeboren, 1856: Denkschr. d. k. Ak. Wiss. Wien, vol. xii, p. 82, pl. ii, figs. 13–17.

D. nana, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 39, pl. ii, figs. 10, 18.

N. (*D.*) *roemeri*, Chapman, 1893: Journ. Roy. Micr. Soc., p. 589, pl. viii, fig. 38.

Remarks.—Recorded from the Upper Hils and Gault of North Germany (Reuss), the Gault of Northern France (Berthelin) and Folkestone (Chapman); the species is still living at depths of not more than 400 fathoms (Brady).

Horizon.—Found in Upper C_2. One specimen.

FRONDICULARIA, Defrance.

Frondicularia gaultina (?), Reuss. (Pl. XIX, Fig. 11.)

Frondicularia gaultina, Reuss, 1860: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xl, p. 194, pl. v, fig. 5.

Remarks.—A broken specimen probably belongs to this species. The base is missing, but the shell resembles Reuss' figure fairly closely. The species is recorded from the *Minimus*-clay of the Rhine (Reuss), the Red Chalk of Speeton (Burrows, Sherborn, & Bailey), and the Folkestone Gault (Chapman).

Horizon.—Found in Upper C_2. One specimen.

RHABDOGONIUM, Reuss.

Rhabdogonium insigne, Reuss. (Pl. XVIII, Fig. 21.)

Rhabdogonium insigne, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 56, pl. v, fig. 2.

Remarks.—Reuss describes this species as very rare in the Upper

Hils to the north-west of Berklingen, and it does not seem to have been recorded since.

Horizon.—Found in D_6 mid. Several specimens.

Marginulina, d'Orbigny.

Marginulina linearis, Reuss. (Pl. XVIII, Fig. 10.)

Marginulina linearis, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 60, pl. v, fig. 15.

M. linearis, Chapman, 1894: Journ. Roy. Micr. Soc., p. 161, pl. iv, fig. 14.

Remarks.—Reuss' figure shows seven chambers and Chapman's six, whereas the specimen found has only four. The species is recorded from the *Minimus*-clay of North Germany (Reuss), the Gault of Northern France (Berthelin) and Folkestone (Chapman).

Horizon.—Present in Upper C_2. One specimen.

Marginulina glabra, d'Orbigny. (Pl. XVIII, Fig. 17.)

Marginulina glabra, d'Orbigny, 1826: Ann. Sci. Nat., vol. vii, p. 259, No. 6; Modèle No. 55.

M. inæqualis, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 59, pl. v, fig. 13.

Remarks.—The specimen is more curved than usual, but in other respects agrees with *M. glabra.* The species is recorded from the *Minimus*-clay of Germany (Reuss), the Red Chalk of Speeton (Burrows, Sherborn, & Bailey), the Folkestone Gault (Chapman), and is still living (Brady) in both shallow and deep water.

Horizon.—Found in B base *c.* One specimen.

Marginulina jonesi, Reuss. (Pl. XVIII, Fig. 15.)

Marginulina jonesi, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 61, pl. v, fig. 19.

M. jonesi, Chapman, 1894: Journ. Roy. Micr. Soc., p. 163, pl. iv, fig. 24.

Remarks.—This is much the commonest species of *Marginulina* in the Speeton Clay, and is fairly abundant. The individuals differ considerably, one specimen (in D_6) showing a passage to *M. striato-costata*, Reuss, which Brady regards as synonymous with *M. costata*, Batsch. In fact, *M. jonesi* is a mere variety of *M. costata*, characterized by fewer and more marked ribs. Other specimens pass into *M. robusta*, Reuss. *M. jonesi* has been recorded from the Upper Hils of Germany and by Chapman from the Folkestone Gault.

Horizon.—Found in B base *b*, Upper C_2, and D_6 mid. Fairly abundant.

Marginulina debilis, Berthelin. (Pl. XVIII, Fig. 23.)

Marginulina debilis, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 35, pl. iii, fig. 28.

M. debilis, Chapman, 1894: Journ. Roy. Micr. Soc., p. 161, pl. iv, fig. 15.

Remarks.—The only specimen found agrees with Chapman's figure in possessing only five chambers. The species is known from the Gault of France (Berthelin) and of Folkestone (Chapman).

Horizon.—Found in Upper C_2. One specimen.

VAGINULINA, d'Orbigny.

Vaginulina incompta (?), Reuss. (Pl. XIX, Fig. 10.)

Vaginulina incompta, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 45, pl. iii, fig. 5.

Remarks.—One specimen probably belongs to this species. The initial cell is rather small and the chambers are somewhat more obliquely set than in Reuss' figure. He describes it as very rare in the Upper Hils Clay at Glückauf.

Horizon.—Found in Upper C_2. One specimen.

Fragments of other species of *Vaginulina* have been found in B base *c*, Upper C_2, and D_6 mid, but too imperfect for specific determination.

CRISTELLARIA, Lamarck.

Cristellaria gracillissima, Reuss. (Pl. XVIII, Fig. 26.)

Cristellaria gracillissima, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 64, pl. vi, figs. 9, 10.

Remarks.—The specimens vary greatly in length and the extent to which the spiral part is developed; some have scarcely any spiral commencement and are very close to *C. fœda*, Reuss (op. cit., p. 64, pl. vi, figs. 11–13). There can be little doubt that the two forms are really one species, and that *fœda* should be dropped as a specific name. It is possible that the form figured by G. R. Vine from the Cambridge Greensand as ? *Trochammina helvetico-jurassica*, Hausler (Proc. Yorks. Geol. Polytech. Soc., N.S., vol. ix, pt. i, p. 28, pl. ii, fig. 16, 1885 (1886)), is *C. gracillissima*. There is a resemblance in the outline of the shell and the mouth, and *C. gracillissima* in some cases appears to have an arenaceous test, owing to the rough prickly surface. The small side-chamber in Vine's figure is, however, very difficult to account for on this hypothesis.

Viewed as a transparent object, the rough surface of *C. gracillissima* is seen to be due to the outgrowths of calcite in optical continuity with the shell.

Horizon.—Common in B base *c*.

Cristellaria acutauricularis (Fichtel & Moll). (Pl. XIX, Fig. 2.)

Nautilus acutauricularis, Fichtel & Moll, 1803: Test. Micr., p. 102, pl. xviii, figs. *g–i*.

Cristellaria polita, Reuss, 1855: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xviii, p. 237, pl. iii, fig. 41.

C. acutauricularis, Brady, 1884: Chall. Rep., vol. ix, p. 543, pl. cxiv, figs. 17*a*, *b*.

Remarks.—The Cristellarians are (with the exception of *Pulvinulina caracolla*) the commonest of all the Foraminifera in the Speeton Clay, and offer great difficulties in specific determination, since no two specimens are quite alike and the number of described species is very great. Figures of the same species given by different authorities differ widely. A number of specimens seem certainly referable to *C. acutauricularis*, whose range in time extends at least as far back as the Lias. The species has been recorded from that formation by

Crick & Sherborn (Journ. Northants. Nat. Hist. Soc., 1891, p. 5, pl., fig. 25), and it is still living. The *Challenger* Expedition found it at depths of from 95 to 2,750 fathoms.

Horizon.—Present in B base *c*, C_1, and D_6 mid. Fairly abundant.

Cristellaria gibba, d'Orbigny. (Pl. XIX, Fig. 9A, B.)

Cristellaria gibba, d'Orbigny, 1839: Foram. Cuba, p. 63, pl. vii, figs. 20, 21.
C. nuda, Reuss, 1861: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xliv, p. 328, pl. vi, figs. 1–3.
C. pulchella, Reuss, 1862: ibid., vol. xlvi, p. 71, pl. viii, fig. 1.
C. gibba, Chapman, 1896: Journ. Roy. Micr. Soc., p. 4, pl. i, figs. 7*a*, *b*.

Remarks.—This species is closely allied to *C. acutauricularis* and has the same range in time. It is recorded from the Upper Hils Clay of Germany (Reuss), the Gault of Folkestone (Chapman), and the Bargate Beds (Lower Cretaceous) of Surrey (Chapman), and from the Red Chalk of Speeton (Burrows, Sherborn, & Bailey). The *Challenger* Expedition found it at depths of less than 500 fathoms.

Horizon.—Present in Upper C_2, Upper C_3, C_{10}. Common in Upper C_2, one specimen from each of the other horizons.

Cristellaria cephalotes, Reuss. (Pl. XVIII, Fig. 20.)

Cristellaria cephalotes, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 67, pl. vii, figs. 4–6.

Remarks.—A single, very thick specimen seems to belong to this species. It has been recorded by Reuss from the Upper Hils and the *Minimus*-clay of Germany.

Horizon.—Found in B base *b*. One specimen.

Cristellaria scitula, Berthelin. (Pl. XIX, Fig. 5.)

Cristellaria scitula, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 53, pl. iii, figs. 3*a–c*.
C. scitula, Chapman, 1894: Journ. R. Micr. Soc., p. 652, pl. x, figs. 7*a*, *b*.

Remarks.—This species has been recorded by Berthelin and Chapman in the Gault of Northern France and Folkestone.

Horizon.—One specimen was found in B base *c*.

Cristellaria chapmani, sp. nov. (Pl. XIX, Fig. 7A, B.)

Description.—Test suboval, with nearly flat sides. It consists of about six chambers, arched, and divided by marked sutural ridges which end abruptly in front, and, near the back, end in a ridge parallel with the dorsal edge. The spiral commencement is obscure. There is no umbilicus. The dorsal edge is smoothly curved, and there is a keel about equally developed with the ridges following the dorsal edge. The aperture is terminal. Length about ·492 mm. (·0194 in.), greatest breadth ·304 mm. (·012 in.).

The form is nearest to *C. bradyana*, Chapman (Journ. Roy. Micr. Soc., 1894, p. 654, pl. x, figs. 13*a*, *b*). It has, however, fewer chambers, the sutural ridges and the dorsal edge are not sinuous, and the dorsal ridges are as well developed as the small keel.

I have named this species after Mr. Frederick Chapman in recognition of the kindly assistance he has always given me in work on the Foraminifera.

Horizon.—Found in B base *c* and Upper C_2. Fairly abundant at both horizons.

Cristellaria crepidula (Fichtel & Moll). (Pl. XIX, Fig. 8.)

Nautilus crepidula, Fichtel & Moll, 1803: Test. Micr., p. 107, pl. xix, figs. *g–i*.
Cristellaria grata, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 70, pl. vii, fig. 14.
C. crepidula, Brady, 1884: Chall. Rep., vol. ix, p. 542, pl. lxvii, figs. 17, 19, 20; pl. lxviii, figs. 1, 2.
C. crepidula, Jos. Wright, 1886: Proc. Belfast Nat. Field Club, App., p. 331, pl. xxvii, fig. 4.

Remarks.—The species ranges from the Lias to Recent. It is recorded (as *C. grata*) by Reuss from the Upper Hils and the *Minimus*-clay of Germany, from the Folkestone Gault by Chapman, the Red Chalk of Speeton by Burrows, Sherborn, & Bailey, and from the Bargate Beds (Lower Cretaceous) of Surrey by Chapman. One specimen agrees most closely with Wright's figure quoted above.

Horizon.—Found in B base *c* (a few specimens) and one specimen from Upper C_2.

Cristellaria turgidula, Reuss. (Pl. XIX, Fig. 1.)

Cristellaria turgidula, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 73, pl. viii, figs. 4*a*, *b*.
C. ingenua, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 54, pl. iii, figs. 20, 21.
C. turgidula, Chapman, 1896: Journ. Roy. Micr. Soc., p. 1, pl. i, fig. 1.

Remarks.—The form is recorded by Reuss from the *Milletianus*- and *Minimus*-clays of Germany, and from the Gault of Northern France and Folkestone by Berthelin and Chapman.

Horizon.—Present in C_1 and Upper C_2. One specimen from C_1, two from C_2.

Cristellaria cultrata (Montfort). (Pl. XIX, Fig. 4.)

Robulus cultratus, Montfort, 1808: Conchyl. Système, vol. i, p. 214, 54^e genre.
Cristellaria cultrata, Brady, 1884: Chall. Rep., vol. ix, p. 550, pl. lxx, figs. 4–6.

Remarks.—A specimen from D_2 base is intermediate between *C. cultrata* and *C. rotulata*. The species is known from the Lias and successive formations to Recent times. Brady states that, as a rule, *C. cultrata* is rarely met with at a depth of less than 100 fathoms.

Horizon.—Found in D_6 mid and ? D_2 base. One specimen in each case.

Cristellaria gaultina, Berthelin. (Pl. XVIII, Fig. 27.)

Cristellaria gaultina, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 49, pl. iii, figs. 15–19.
C. gaultina, Chapman, 1896: Journ. Roy. Micr. Soc., p. 7, pl. i, figs. 10*a*, *b*, 11.

Remarks.—The species has been recorded from the Gault of Northern France and Folkestone by Berthelin and Chapman. According to Chapman the *C. cultrata* of the Red Chalk of Speeton belongs to this species.

Horizon.—Present in B base *c* and D_6 mid. One specimen in each bed.

Cristellaria sternalis, Berthelin. (Pl. XIX, Fig. 3.)

Cristellaria sternalis, Berthelin, 1880: Mém. Soc. géol. France, sér. III, vol. i, No. 5, p. 54, pl. iii, figs. 2*a*, *b*.
C. sternalis, Chapman, 1896: Journ. Roy. Micr. Soc., p. 8, pl. ii, figs. 1*a*, *b*.

Remarks.—The only specimen found has a smaller keel than the one figured by Chapman. The species is known from the Gault of Northern France and Folkestone.

Horizon.—Present in B base *c*. One specimen.

Cristellaria orbiculata (Roemer). (Pl. XIX, Fig. 6.)

Planularia orbiculata, Roemer, 1842: Neues Jahrbuch, p. 278, pl. vii B, fig. 6.

Remarks.—Described by Roemer from the Hils Clay of Escherhausen, which Reuss (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 8, 1862) thinks is probably the Speeton Clay of his classification; it does not seem to have been found since.

Horizon.—Found in B base *c*. One specimen.

Cristellaria rotulata (Lamarck). (Pl. XVIII, Fig. 25.)

Lenticulites rotulata, Lamarck, 1804: Annales de Muséum, vol. v, p. 188, No. 3; Tableau Encycl. et Méth., pl. cccclxvi, fig. 5.
Cristellaria münsteri, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 77, pl. ix, figs. 3*a*, *b*, 4*a*, *b*.
C. rotulata, Brady, 1881: Chall. Rep., vol. ix, p. 547, pl. lxix, figs. 13*a*, *b*.

Remarks.—This is by far the commonest species of *Cristellaria* in the Speeton Clay of Yorkshire, and, with the exception of *Pulvinulina caracolla*, is much the commonest of all the Foraminifera in that formation. A few specimens are doubtfully referred to *C. rotulata*, var. *macrodiscus*, Reuss (Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 78, pl. ix, figs. 5*a*, *b*, 1862).

C. rotulata is known from the Middle and Upper Hils and the Speeton Clay of North Germany (Reuss), from the Red Chalk of Speeton, the Gault of Folkestone and Northern France, and many other Cretaceous deposits, and probably ranges back as far as the Ordovician System (Ulrich, Journ. Cincin. Soc. Nat. Hist., vol. v, p. 119, pl. v, figs. 2, 2*a*, 1882 (?)). It is still common in many parts of the world, and is found at all depths (Brady).

Horizon.—Present in B base *b*, B base *c*, C_1, C_2, C_3, C_9, D_3, D_6. Abundant.

Sub-family POLYMORPHINÆ.

POLYMORPHINA, d'Orbigny.

Polymorphina fusiformis, Roemer. (Pl. XIX, Fig. 12.)

Polymorphina (*Globulina*) *fusiformis*, Roemer, 1838: Neues Jahrb. für Min., p. 386, pl. iii, fig. 37.
P. (*G.*) *angusta*, Egger, 1857: Neues Jahrb. für Min., p. 290, pl. xiii, figs. 13–15.
P. lanceolata, Reuss, 1851: Zeitschr. d. deutsch. geol. Gesell., vol. iii, p. 83, pl. vi, fig. 50.
Globulina prisca, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 79, pl. ix, fig. 8.
Polymorphina fusiformis, Brady, Parker, & Jones, 1870: Trans. Linn. Soc., vol. xxvii, p. 219, pl. xxxix, figs. 5*a*–*c*, and woodcut *e*, p. 220.

Remarks.—Brady has subdivided this species again into *P. angusta*, Egger, and *P. lanceolata*, Reuss (Chall. Rep., vol. ix, p. 563, 1884), but Chapman reunites them (Journ. Roy. Micr. Soc., 1896, p. 11, pl. ii, fig. 9). A number of specimens have been found, and they show transitional stages between the types recognized by Brady. The form is recorded by Reuss from the Upper Hils and the *Minimus*-clay of Germany, by Berthelin (Mém. Soc. géol. France, sér. III, vol. i, p. 57, pl. iv, figs. 20*a*, *b*, 1880) from the French Gault, and by Chapman from the Gault of Folkestone. Burrows, Sherborn, & Bailey record it as *P. lactea* in the Red Chalk (Journ. Roy. Micr. Soc., 1890, p. 561), and it is still living. Brady states that it ranges down to 2,400 fathoms.

Horizon.—Fairly abundant in Upper C_2; a single specimen in B base *c*.

Polymorphina problema, d'Orbigny. (Pl. XIX, Fig. 13.)

Polymorphina (*Guttulina*) *problema*, d'Orbigny, 1826: Ann. Sci. Nat., vol. vii, p. 266, No. 14; Modèle No. 61.
P. (*G.*) *communis*, d'Orbigny, loc. cit., p. 266, pl. xii, figs. 1–4; Modèle No. 62.
P. problema, Brady, 1884: Chall. Rep., vol. ix, p. 568, pl. lxxii, figs. 19, 20; pl. lxxiii, fig. 1.

Remarks.—The species is recorded by Chapman (*P. communis*) from the Gault of Folkestone (Journ. Roy. Micr. Soc., 1896, p. 13, pl. ii, fig. 15) and the Lower Cretaceous of Surrey (Q.J.G.S., vol. l, p. 716, 1894); by Berthelin from the Gault of France, as *P. cretacea* (Mém. Soc. géol. France, sér. III, vol. i, p. 58, 1880), and from the Red Chalk of Speeton, as *P. gibba*, by Burrows, Sherborn, and Bailey (Journ. Roy. Micr. Soc., 1890, p. 561), and it is still living. The greatest depth from which it was recorded by the *Challenger* Expedition was 155 fathoms.

Horizon.—Present in Upper C_2. One specimen.

EXPLANATION OF PLATE XVIII.

All figures are magnified 50 diameters except Fig. 25.

FIG. 1. *Reophax scorpiurus*, Montfort.
,, 2. *Bigenerina nodosaria*, d'Orb.
,, 3. *Haplophragmium latidorsatum* (Bornemann). 3*a*, lateral aspect; 3*b*, oral aspect.
,, 4. *Gaudryina filiformis*, Berthelin.
,, 5. *Ammodiscus gordialis* (Jones & Parker).
,, 6. *Lagena globosa* (Montagu).
,, 7. *Nodosaria* (*Dentalina*) *fontannesi*, Berthelin.
,, 8. *Lagena apiculata*, Reuss, var. *danfordi*, var. nov.
,, 9. *Nodosaria* (*Dentalina*) *roemeri*, Neugeboren.
,, 10. *Marginulina linearis*, Reuss.
,, 11. *Nodosaria* (*Glandulina*) *lævigata*, d'Orb., var. *strobilus*, Reuss.
,, 12. *Lagena apiculata*, Reuss.
,, 13. *Nodosaria* (*Dentalina*) *lorneiana*, d'Orb.
,, 14. *Lagena lævis* (Montagu).
,, 15. *Marginulina jonesi*, Reuss.
,, 16. *Nodosaria calomorpha*, Reuss.
,, 17. *Marginulina glabra*, d'Orb.
,, 18. *Nodosaria hispida*, d'Orb. Broken specimen.
,, 19. *N.* (*Dentalina*) *siliqua* (?), Reuss. Broken specimen.

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Foraminifera, Speeton Clay, Yorkshire.

FIG. 20. *Cristellaria cephalotes*, Reuss.
,, 21. *Rhabdogonium insigne*, Reuss. 21*a*, lateral aspect; 21*b*, oral aspect.
,, 22. *Nodosaria (Dentalina) legumen*, Reuss.
,, 23. *Marginulina debilis*, Berthelin.
,, 24. *Nodosaria (Dentalina) communis*, d'Orb.
,, 25. *Cristellaria rotulata* (Lamarck). Magnified 33⅓ diameters.
,, 26. *C. gracillissima*, Reuss.
,, 27. *C. gaultina*, Berthelin.

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

III.—Some new Rock-building Organisms from the Lower Carboniferous Beds of Westmorland.

By Professor E. J. Garwood, M.A., F.R.S., F.G.S.

(PLATES XX AND XXI.)

In my account of the Lower Carboniferous rocks of the North-West of England, published in 1912, I figured an organism, probably the thallus of a calcareous alga, which plays an important part as a rock-builder at the base of the *Seminula gregaria* sub-zone in Westmorland and Lancashire.[1] More recently, at the meeting of the British Association in Birmingham,[2] I pointed out the need of some distinctive name for this important form, and suggested for it the generic name of 'Ortonella', from the village of Orton, near Tebay, in the neighbourhood of which this fossil is specially abundant. Two other structures were mentioned at the same time which occur constantly in microscopic sections of the Lower Carboniferous rocks of the North-West of England and elsewhere. The first of these was alluded to under the general descriptive term 'festoon structure', and the other was referred to Gürich's somewhat obscure genus *Spongiostroma*. In view of the zonal value of these organisms in the North-Western Province and the probability that they will be found to be widely distributed in the Lower Carboniferous rocks elsewhere, I propose here to give a somewhat fuller description of these forms than could be attempted in the limits of a presidential address.

Ortonella, gen. nov. (Pl. XX, Figs. 1–4.)

Mode of Occurrence.—The remains of this organism occur in the form of sub-spheroidal nodules varying in size from that of a marble to that of a tangerine orange, the largest example met with having a diameter of 5 cm. (Fig. 1). The fractured surfaces of the nodules show a porcellanous texture and a uniform rich brown tint, while a distinct concentric arrangement is usually noticeable. In transparent slices a fibrous structure radiating from the centre can also be observed with a strong hand lens. The smaller examples resemble, in general appearance, the nodules of *Solenopora* which occur in the underlying sub-zone in Westmorland and likewise the nodules of *Mitcheldeania* which are found so abundantly in the Lower Carboniferous deposits of Mitcheldean and North Cumberland.

Under the Microscope.—The thallus is seen to consist of a series of fine ramifying tubes which radiate from the centre of the nodule in

[1] Q.J.G.S., vol. lxviii, p. 449, pl. xlvii, fig. 2, November, 1912.

[2] Rep. Brit. Assoc. 1913, Section C; also Geol. Mag., Dec. V, Vol. X, pp. 440, 490, 545, 1913.

every direction. The tubes vary slightly in size, the lumina having on an average a diameter of about 32 μ, and individual tubes show a nearly uniform diameter throughout. The tubes are typically straight or so slightly undulating that in thin slices passing approximately through the centre of the nodule many of these tubes remain in the plane of the section for considerable portions of their length (Fig. 2).

The tubes are circular in cross-section, completely separated, and often widely spaced. They show marked dichotomous branching (Figs. 3, 4), the angle of divergence of the branches being usually about 40°, and there appears to be a tendency for this branching to take place in several neighbouring tubes at about the same distance from the centre of the nodule. The tubes appear to be completely devoid of transverse partitions, and no trace of perforations has been observed in their walls. They are now filled partly with crystalline calcite and partly with fine dark marly sediment, while the spaces between the tubes are occupied by similar materials. The concentric appearance of the nodules seems to be due partly to the increased proximity of the tubes where bifurcation occurs and partly to the denser character of the matrix, which has remained more completely entangled where the tubes are in closer approximation.

Genotype.—*Ortonella furcata*, sp. nov. (Pl. XX, Figs. 1–4.) All the examples so far met with in Westmorland belong apparently to one species, which, on account of its marked dichotomous branching, we may appropriately speak of as *Ortonella furcata*.

Horizon.—In the algal layer at the base of the *Seminula gregaria* sub-zone, *Athyris glabristria* zone; Lower Carboniferous, Westmorland and Lancashire.

Localities.—Orton; Ravenstonedale; Shap; Eskrigg Wood, near Summerlands—in Westmorland; and near Low Meathop in Lancashire also, sparingly, at about the same horizon immediately below the Fell Sandstone in North Cumberland and North-West Northumberland. I have also met with a few examples, referable to this species but with somewhat finer tubes, in the *Modiola* beds of Dr. Vaughan's classification near the base of the Lower Carboniferous rocks in the Avon Gorge.

Resemblances and Differences.—In general appearance under the microscope, this organism most closely resembles the genus *Mitcheldeania* described by Mr. Wethered from the Lower Limestone Shales of the Forest of Dean,[1] a fuller account of which was subsequently given by the late Professor Nicholson in 1888,[2] from the Lower Carboniferous rocks of Kershope Foot on the Scottish Border.

Our genus resembles *Mitcheldeania gregaria*, Nich., in the radiating mode of arrangement of its tubes and in the fact that it exhibits dichotomous branching. It differs from it, however, in the smaller size of the tubes, their straight and more uniform character, and their much wider spacing. Again, though both genera exhibit dichotomous branching this takes place much more frequently and

[1] Geol. Mag., Dec. III, Vol. III, p. 535, Pl. XIV, Fig. 6, 1886, and Proc. Cotteswold Nat. Club, vol. ix, p. 77, 1886.

[2] Geol. Mag., Dec. III, Vol. V, pp. 16–19, Figs. 1, 2, 1888.

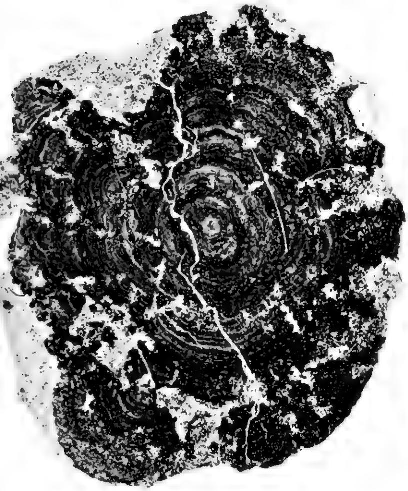

Fig. 1. $\frac{1}{1}$.

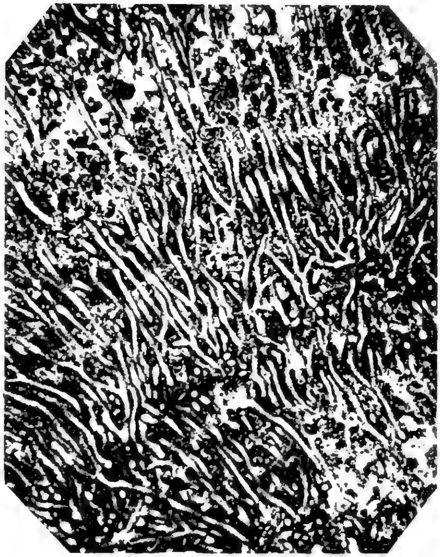

Fig. 2. × 20.

Fig. 3. × 55.

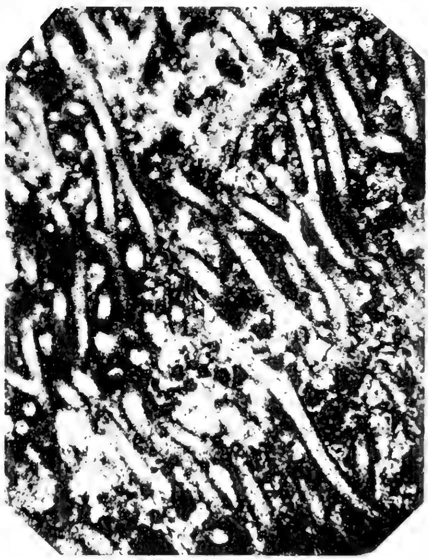

Fig. 4. × 55.

E. J. Garwood, photo. *Bemrose & Sons Ltd., Collo.*

Ortonella furcata.

uniformly in *Ortonella* than in *Mitcheldeania*, while the angle of divergence of the branches is also much greater in *Ortonella*, thus giving rise to the marked difference in the spacing of the tubes in the two genera. It also differs from *Mitcheldeania*, as described by Nicholson, in the absence of cross partitions to the tubes and the imperforate character of the walls, and also in the general absence of the finer series of tubes which Wethered and Nicholson regard as an essential character of *Mitcheldeania* (Pl. XXI, Fig. 2). The structures described by Nicholson as cross partitions in the tubes are, however, very irregular and frequently entirely absent in the Cumberland examples of *M. gregaria*, while the perforations in the cell-walls mentioned by the same author are very obscure, and, as I have already stated,[1] I have been unable to discover any true pores in the Cumberland specimens of *M. gregaria*, even in those which I have collected from Nicholson's type locality at Kershope Foot. It is possible, therefore, that the large pores figured by Nicholson are in reality the elbows of the undulating tubes intersected by the plane of the section.

As regards the finer series of tubes in *Mitcheldeania* (Pl. XXI, Fig. 2), these appear to be typically present in examples of *M. Nicholsoni* and in most of the larger specimens of *M. gregaria*. I have, however, frequently found them to be absent from small examples of *M. gregaria*, the nodules in this case being entirely made up of the coarser tubes. At the same time it is not an uncommon occurrence to find small nodules entirely composed of the finer tubes without any traces of the coarser forms, and it is open to question whether the two sets of tubes necessarily belong to the same organism. This doubt seems to be strengthened by the occurrence, though rarely, of specimens of *Ortonella* in Westmorland with tufts of fine tubules associated with them, which are indistinguishable from the finer tubes in *M. gregaria*.

Other organisms to which *Ortonella* bears some resemblance are *Girvanella*, Nich., and *Sphærocodium*, Rothpl. It differs, however, from these genera in the radial arrangement of its tubes, which in *Girvanella* and *Sphærocodium* lie in concentric layers round the nucleus. Again, though Rothpletz has described dichotomous branching in *Girvanella*, this is certainly obscure in most British examples, including Nicholson's genotype from Girvan. It appears, however, from Dr. Rothpletz's description, to occur in *Sphærocodium Bornemanni*.

Systematic Position.—The genus *Ortonella*, as shown above, seems to be most nearly allied to *Mitcheldeania* and *Sphærocodium*, and, as both these forms appear referable to the calcareous algæ, *Ortonella* may also be provisionally placed among the Thallophyta. As regards its more definite systematic position, it seems to be most nearly related to the Siphoneæ, but, as Professor Seward cautiously remarks regarding *Girvanella*, *Siphonema*, and *Sphærocodium*, "It is wiser to regard such tubular structures as closely allied organisms, which are

[1] Rep. Brit. Assoc., Section C, 1913, and Geol. Mag., Dec. V, Vol. X, pp. 440, 490, 545.

probably algæ, but too imperfectly known to be referred to any particular family."[1]

APHRALYSIA,[2] gen. nov. (Pl. XXI, Figs. 3, 4.)

The macroscopic characters of this organism can only be generally inferred, as specimens have not been isolated from the matrix. In translucent sections of the rock, however, these organisms are seen to occur as thick incrustations surrounding fragments of various organisms and, if isolated, they would appear as small nodules up to 10 mm. in diameter, having a slightly lobulate surface, thus resembling nodules of *Girvanella* or *Solenopora*.

Under the microscope the nodules are seen to be built up of a series of semicircular and semi-elliptical plates arranged in irregular alternating rows, having the convex surfaces of the plates directed uniformly outwards away from the centre of growth, giving a general appearance of wreaths of bubbles, encrusting fragments of shells, or the thalli of *Ortonella* and other algal forms. The growth usually starts with small plates resembling hollow blisters attached by their edges to the surface of the object which serves as a nucleus. The size of the blister-like cells increases in the succeeding row, and usually averages ·12 mm. in height in the centre. The length of the cells varies according to the position of the sections, but the height of the arch is remarkably uniform in the majority of cases, whatever the length of individual cell. These curved plates, bounding the outer surfaces of the cells, sometimes occur as very thin dark lines, but they are more frequently represented by a pale orange-coloured film or stain. This colouring matter may extend inwards so as to occupy a quarter or even a third of the cavity, the thickness depending apparently on the angle made by the wall with the plane of the section. There is a complete absence of circular sections, so that the cells cannot be tubular in character. The structure is thus shown to consist of a series of alternating rows of elongated, highly arched plates, each plate resting with its edges supported by the plates of the row below, exactly like a tangle of soap bubbles or a mass of foam.

No other definite structures can be made out, but occasionally in sections cut tangentially to the surfaces of the nodules a few curved plates may be observed (exactly similar in structure and colour to the boundary walls) which appear to divide up some of the more elongate cells. These may, however, be the edges of other cells cut by the plane of the section. This organism is frequently intergrown with layers of a flocculent deposit which may be classed under the general term '*Spongiostroma*'.

The exact nature of *Aphralysia* is somewhat doubtful. Its mode of growth and its intimate association with *Ortonella* and '*Spongiostroma*' would appear to suggest algal affinities, but the comparatively large size of its cells and their mode of growth differentiate it from any examples of fossil calcareous algæ known from the Lower Palæozoic rocks.

[1] Seward, *Fossil Plants*, vol. i, p. 160, 1898.
[2] 'Chain of foam.' From ἄφρος, 'foam,' and ἅλυσις, 'a chain.'

Fig. 1. Spongiostroma. × 2·5.

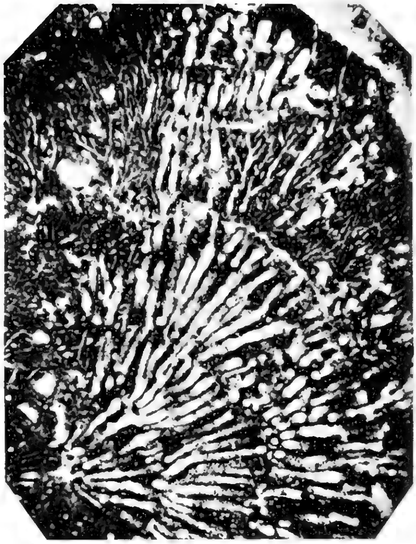

Fig. 2. Mitcheldeania. × 26.

Fig. 3. Aphralysia. × 13.

Fig. 4. Aphralysia. × 30.

E. J. Garwood, photo. *Bemrose & Son Ltd., Collo.*

Though the material so far to hand does not afford sufficient evidence to warrant our assigning to it a definite systematic position, there can be no doubt as to its importance as a rock-forming organism.

Genotype.—Aphralysia carbonaria, sp. nov. (Pl. XXI, Figs. 3, 4.) The specimens so far met with appear to belong to only one species, for which on account of its widespread occurrence in the Lower Carboniferous rocks we suggest the specific name of '*carbonaria*'.

Horizons and Localities.—It occurs abundantly in the Lower Carboniferous rocks of the North-West of England at the base of the *Seminula gregaria* sub-zone. In the Shap and Ravenstonedale districts of Westmorland; also at the same horizon at Low Meathop in the Arnside district; more sparingly in the *Solenopora* sub-zone in Stone Gill, Ravenstonedale; in the upper *Dibunophyllum* sub-zone (*Girvanella* Nodular Band) at Humphrey Head in the Grange district; in association with *Mitcheldeania gregaria* in the Whitehead Limestone at Mitcheldean; at about the same horizon again in North Cumberland and near Tosson in Northumberland; also in the *Modiola* beds underlying the Bryozoa bed in the Avon Gorge, Clifton, exposed in the lower railway cutting near Cook's Folly.

'Spongiostroma.' (Pl. XXI, Fig. 1.)

In 1906 Gürich described and figured a number of somewhat obscure structures from the Dinantian rocks of the Namur district (under the generic names *Spongiostroma*, *Malacostroma*, etc.) which he regarded as encrusting Foraminifera.[1] More recently Professor Rothpletz has described two species of *Spongiostroma* (*S. balticum* and *S. Holmi*) from the Silurian rocks of Gotland.[2] Gürich's reference of these structures to the Protozoa appears to be decidedly speculative, while the features which he selects for the subdivision of the different forms into genera and species are very indefinite, and the detailed structure often varies greatly, even in the same specimen.

In the Lower Carboniferous rocks of Westmorland we meet with many similar structures which in places contribute largely to the formation of the deposit. They occur especially in the 'Algal Layer' at the base of the *Seminula gregaria* sub-zone, associated with *Ortonella* and *Aphralysia* (Pl. XXI, Figs. 3, 4), and occasionally form undulating layers several inches in thickness. I have observed similar structures in the rocks of North Cumberland and West Northumberland and the Border country, also in the Forest of Dean, the Avon Gorge, and South Wales,[3] and it is probable that they will be found to be widely spread in shallow-water deposits of Dinantian age in Europe.

In transparent slices under low magnification they frequently show a general appearance of stratification lying roughly parallel to the bedding-planes (Pl. XXI, Fig. 1), while fine layers of a similar deposit are often seen under higher powers to be intergrown

[1] *Mém. du Mus. Roy. d'Hist. Nat. de Belgique*, t. iii.
[2] *Kungl. Svenska Vetenskap. Hand.*, Bd. xliii, No. 5, 1908.
[3] In specimens sent me by Mr. C. H. Cunnington.

concentrically with specimens of *Ortonella* and *Aphralysia* (Pl. XXI, Figs. 3, 4). Under the microscope no definite cell-structure can be made out, and the general appearance is that of an indefinite flocculent precipitate of carbonate of lime which has the appearance of having been thrown down from solution as the result of the abstraction of $C O_2$ from water containing calcium bicarbonate in solution. The character of these structures, coupled with the general absence of definite mechanical and organic fragments, where they occur, points strongly to their organic origin, while their constant association with *Ortonella*, *Mitcheldeania*, and *Solenopora* would suggest that the conditions under which they were formed were of a lagoon character suitable for the growth of marine algæ. At the same time the absence of definite cell-structure suggests that they represent the insoluble $Ca C O_3$ precipitated in an amorphous condition as the result of absorption of $C O_2$ from the water by growing plants rather than definite structures built up in the cells of calcareous algæ.[1] General precipitation of this kind is well known to botanists at the present day. Thus the famous 'Sprudelstein' of Carlsbad has often been stated to have originated in this manner, though this has been disputed by some recent observers. There cannot, however, be any doubt regarding the action of certain plants in this connexion.

During the progress of the bathymetrical survey of the Scottish lochs, abundant precipitation of calcium carbonate, due to plant action, was observed. In addition to lime-encrusted Characeæ in the lochs of Lismore, lime-encrustations were observed on the stones of the shore formed by minute lithophilous algæ, in the process of their metabolism, while certain plants such as *Myriophyllum spicatum* and *Potamogeton* were found to produce heavy precipitates of $Ca C O_3$. The former plant is stated by Mr. George West[2] to be so heavily coated with encrustations of carbonate of lime that the plants are often unable to rise to the surface for the purpose of pollenization. Were it not for the fact that the majority of the Scottish lochs lie in areas where the rocks are practically devoid of lime, this phenomenon would doubtless have been met with more frequently.

In the Swiss lakes also (Geneva, Neuchâtel, etc.) the blue-green algæ, according to Chodat, cause important precipitation of $Ca C O_3$. Indeed, in recent years there has been a growing conviction among writers on lake deposits (C. A. Davis,[3] Wesenburg-Lund,[4] Weltner,[5] Passarge,[6] and others) that the lime deposits in lakes are chiefly, if not entirely, due to organisms, among which plants often play a very important part. It seems highly probable, then, that similar amorphous deposits are also taking place in shallow seas, especially where lagoon conditions prevail and algæ flourish. Our knowledge of such

[1] Thus, if water is saturated with calcium bicarbonate, then for each gram of $C O_2$ abstracted by plants, 2·3 grams of $Ca C O_3$ are precipitated.

[2] *Bathymetrical Survey of the Fresh-water Lochs of Scotland*, vol. i, p. 213, 1910.

[3] *Journal of Geology*, Chicago, vol. viii, p. 485; vol. ix, p. 491.

[4] *Meddel fra Dansk Geolog. Foren. Kobenhavn*, vii, 1.

[5] *Archiv f. Naturges.*, vol. lxxi, p. 277.

[6] *Jahrb. d. Königl. Preuss. Geol. Landesanst*, vol. xxii, p. 79.

deposits appears at present to be very scanty, and further investigation is greatly needed.

EXPLANATION OF PLATES XX AND XXI.

PLATE XX.

FIG. 1. *Ortonella furcata*, gen. et sp. nov. Section through a typical nodule. Natural size. Base of the *Seminula gregaria* sub-zone, Ravenstonedale, Westmorland.

,, 2. *O. furcata.* Thin section through above. × 20.

,, 3, 4. *O. furcata*, showing dichotomous branching of tubes. × 55.

PLATE XXI.

FIG. 1. *Spongiostroma* cf. *Malacostroma concentricum*, Gürich. × 2·5. Base of the *Seminula gregaria* sub-zone, Fawcett Mill, near Orton, Westmorland.

,, 2. *Mitcheldeania gregaria*, Nich. × 26. Showing coarse and fine tubes. Zone of C_1–C_2 of Dr. Vaughan's classification. Scully Grove, Mitcheldean.

,, 3. *Aphralysia carbonaria*, gen. et sp. nov. × 13. Intergrown with layers of a flocculent deposit—'*Spongiostroma.*'

,, 4. *A. carbonaria*, gen. et sp. nov. × 30. From the 'Algal Band' associated with *Ortonella*. Base of *Seminula gregaria* sub-zone, Wath, near Orton, Westmorland.

IV.—GYPSUM AND ANHYDRITE IN GENETIC RELATIONSHIP.

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IN certain geological horizons where there is evidence of continuous deposition of salts from the waters of inland basins, gypsum and anhydrite are found closely associated, while in other similar horizons gypsum may occur with apparently no trace of anhydrite. Some Upper Silurian occurrences in North America, the Lower Carboniferous of Eastern Canada, and the Zechstein of Northern Germany are illustrative of the association of both minerals, while in more recent gypsum horizons anhydrite seems to appear less frequently. Even in the one horizon anhydrite is found to be of only local occurrence. In New York and in Michigan the Salina formation contains both gypsum and salt deposits, but practically no anhydrite. In Manitoba, on the other hand, in an Upper Silurian formation which cannot be definitely correlated with the Salina of New York, but which is at any rate of approximately the same age, gypsum and anhydrite occur in the most intimate relationship.

The conditions of stability of gypsum and of anhydrite, whether in presence of water or of salt solutions, were investigated by van't Hoff and his co-workers by vapour-tension methods. The relationship of both forms to the half-hydrate ($CaSO_4 . \frac{1}{2}H_2O$), which is obtained by ordinary calcination processes, and to 'soluble anhydrite', which is formed when precipitated gypsum is maintained at temperatures

60°–90° C. *in vacuo* in contact with phosphorus pentoxide, was also studied. The results may be briefly tabulated as follows[1]:—

Natural anhydrite transforms into gypsum—
(*a*) At 30° C. in presence of a saturated solution of sodium chloride.
(*b*) At 66° C. in presence of water.

Soluble anhydrite transforms into gypsum—
(*a*) At 65° C. in presence of a saturated solution of sodium chloride.
(*b*) At 89° C. in presence of water.

Half-hydrate transforms into gypsum—
(*a*) At 11° C. in presence of a saturated solution of magnesium chloride.
(*b*) At 76° C. in presence of a saturated solution of sodium chloride.
(*c*) At 101·5° C. under atmospheric pressure.
(*d*) At 107° C. in presence of water.

If, then, at a certain stage of evaporation an inland sea is saturated as regards calcium sulphate and sodium chloride, and if the temperature is not below 30° C., anhydrite will form. The frequent association of anhydrite and salt beds in nature would consequently seem to indicate, at the time of deposition, rather high temperatures in the bodies of water from which these minerals were precipitated. This view has usually been taken in connexion with the Stassfurt Beds, and was suggested by van't Hoff as a geological deduction from his experimental work. If, however, gypsum beds, intercalated with beds of salt, be in course of time buried to depths of 1,500 feet or more, and if the average surface temperature be taken as 15° C., the gypsum is, under such conditions, above transformation temperature, and will presumably go gradually over into anhydrite. Arrhenius and Lachmann[2] believe that in the case of the Stassfurt sulphates the faunal evidence is against the probability of temperatures so high as 30° C. in the inland seas of Northern Germany in late Permian times, and that the anhydrite of Stassfurt is a transformation product from originally deposited gypsum. The reverse reaction would necessarily take place, and gypsum would again be formed, in the case of the anhydrite horizon reaching a higher relative level owing to the denudation of the overlying beds, or in the case of the abstraction of the associated salt beds by solution.

In the course of an investigation, for the Geological Survey of Canada, of the gypsum and the salt horizons in the limestones of Palæozoic age in Manitoba, the writer has had occasion to examine a surface exposure of gypsum, with associated anhydrite, at Gypsumville, the present terminus of the Canadian Northern Railway branch line which skirts the east side of Lake Manitoba. The following section was obtained from the face of the quarry that is now being operated:—

(*e*) Surface capping (gypsite and soil) .	1–3 feet.
(*d*) Red argillaceous gypsum	29 ,,
(*c*) White foliated gypsum	75 ,,
(*b*) Bluish-grey anhydrite	25 ,,
(*a*) Hard reddish gypseous rock . . .	5 ,,

[1] *Untersuchungen über die Bildungsverhältnisse der ozeanischen Salzablagerungen*, 1912, p. 189.
[2] *Geologische Rundschau*, Bd. iii, Hft. iii, p. 141.

The immediately underlying beds are not exposed in this locality, but from the evidence of a core section they appear to be a reddish calcareous clay. The anhydrite forms heavy beds 2–4 feet thick, which show no evidence of disturbance. The overlying white gypsum beds are 2–4 inches thick, and are sharply folded. At the quarry there is a dip, which is only of local significance, towards the north; consequently the anhydrite appears only at the south end of the quarry. The line of contact between the gypsum and anhydrite follows fairly closely the bedding-plane, wherever the top of the anhydrite beds is exposed. A similar close association of the two minerals may be observed in several of the gypsum exposures which occur in the Gypsumville district, and which cover in the aggregate an area of nearly 5½ square miles. In one locality, 6 miles north-east of the quarry, anhydrite occurs at the surface, and is found by boring to extend at least 90 feet vertically downwards, entirely free from gypsum; while half a mile further east an exposure of gypsum of considerable extent appears, with only occasional outcrops of anhydrite.

The horizon in which these surface exposures lie is near the top of the Upper Silurian. The highest beds of the Silurian in Manitoba, as determined by Kindle,[1] skirt the western side of the gypsum outcrop, and consist of thin-bedded magnesian limestones, rather poor in fossils, but characterized by the presence of *Leperditia hisingeri*. These beds overlie the gypsum. Underlying the gypsum horizon are dolomites and dolomitic limestones, in which but few fossils have been found. They belong to the Stonewall Series, which is probably the western equivalent of the Niagara and Guelph horizons in the east. The Palæozoic beds, which form in this locality a western fringe to the Canadian Shield, dip almost imperceptibly towards the south-west. The topography is relatively flat, the elevations of the surfaces of Silurian and Devonian formations ranging from 750 to 900 feet above sea-level. An escarpment of soft Cretaceous shales rises rather sharply from the Upper Devonian Limestones on the west side of Lake Winnipegosis and Lake Manitoba to a height of 2,500 feet above sea-level. The distance from the Gypsumville quarry (elevation 850 feet) to the top of the escarpment, measured in an east and west line, is approximately 80 miles. Almost certainly these Cretaceous shales formerly extended eastwards over the gypsum exposures, which were consequently buried to a depth of 1,700 feet at least. While salt has not been found in association with the gypsum horizon, the presence of glauberite ($CaSO_4 . Na_2SO_4$) from a core obtained by drilling at the quarry shows that the concentration of sodium ions was high in the solution from which the calcium sulphate was precipitated; and on the west side of Lake Winnipegosis numerous salt springs occur in the Upper Devonian, so that the gypsum horizon, when deeply buried, was probably saturated with a brine solution. Conditions may then have been favourable for the transformation of gypsum into anhydrite when the Upper Silurian was buried beneath the Cretaceous shales. The problem in this case

[1] Geological Survey of Canada, Summary Report, 1912.

and in similar cases is whether the anhydrite was originally deposited, or was formed by transformation at a later stage, when, owing to increasing depth of sedimentation, a temperature of 30° C. was undoubtedly reached.

In seeking to explain the origin of deposits such as these, one may consider the two alternatives that are generally offered: First, the theory of Ochsenius,[1] that the salts have been deposited from an arm of the sea, which is in only partial communication with the outer ocean; second, the theory that limestones have been converted into the sulphates by the action of water containing SO_4 ions. In the case under consideration the gypsum does not grade laterally into limestone: basal red beds occur, and one complex sulphate at least has been found. Such facts are not in accord with the theory that the beds were originally limestones. On the other hand, the sequence gypsum, anhydrite, and gypsum (with glauberite) is explicable on the assumption of an evaporating basin, separated from the outer ocean by a bar over which calcium salts might reach the inner evaporating pan. The more soluble chlorides of sodium and potassium, sulphates of magnesium and complex salts, have not been found in this locality; but brines which reach the surface in Upper Devonian limestones contain a high percentage of potash, and may be genetically connected with this horizon.

The applicability of Ochsenius' hypothesis to the Stassfurt salts has recently been questioned by Walther,[2] who believes that the salts were precipitated from an inland basin entirely cut off from the sea, that, as the shallower parts of the lake dried up, the salts were redissolved and carried down to the deep basins, and that only such deep basins are represented by the present distribution of the deposits. Grabau[3] has made a still wider application of the desert hypothesis in his explanation of the Salina deposits of New York and Michigan. He considers that the land surface of the Niagara Limestones, reworked by weathering agents under desert conditions, supplied—mainly through the connate waters with which the limestones were impregnated—the salts which were finally carried down, by streams due to intermittent rains, into circumscribed desert basins. The annual rings at Stassfurt might be accounted for, according to Walther, as due to salts carried down after successive rainfalls; and the same authority considers that the absence of fossils cannot be explained if communication with the open sea remained established during the whole period of precipitation. In the Gypsumville deposits there are no annual rings; no indication of subaerial weathering has been found in the underlying rock; the homogeneous character of the heavy anhydrite beds is difficult of explanation on a desert erosion hypothesis; and the absence of fossils in the anhydrite-gypsum section might be accounted for, as at Stassfurt,[4] by postulating a rather extended bar where communication was made with the outer ocean,

[1] *Die Bildung der Steinsalzlager und ihrer Mutterlangensalze*, 1877.
[2] *Lehrbuch der Geologie von Deutschland*, 1910.
[3] Mining and Metallurgical Society of America, Bulletin 57, p. 39; also *Principles of Stratigraphy*, 1913, ch. ix.
[4] Arrhenius & Lachmann, l.c., p. 142.

so that the organisms which entered these inimical waters might be able to effect their escape. In the district in question such a barrier would, in all probability, lie far towards the north. In the limestones of Devonian age the fauna is distinctly European in type, and seems not to have commingled with that of the New York and Michigan Devonian seas till late Devonian times. These Devonian limestones in the Mackenzie River basin overlap the Silurian beds on the edge of the Archæan shield, and the character of the underlying Silurian in that district has not been ascertained. At a single exposure, however, on the Bear River, gypsum is found interstratified with dolomites.[1]

To return to the main problem before us, the primary or the secondary character of anhydrite. It is very evident that transformations take place with extreme slowness. In the district to which particular attention has been devoted in this paper, the Cretaceous shales were elevated, and in all probability eroded, in early Tertiary times. Since that time anhydrite has been the unstable modification. Notwithstanding this, solid anhydrite may be found, as already indicated, to a depth of over 90 feet, with no gypsum on top. It is true that glacial erosion has taken place since that time, but boulders of compact anhydrite which lie on the surface fully exposed to atmospheric influence are surrounded by only a thin film of gypsum. Geological evidence points unmistakably to a very prolonged lag in the transformation anhydrite → gypsum, and it is not at all likely that at temperatures not much above 30° C. the change gypsum → anhydrite goes on more rapidly. Indeed, the burying of gypsum under considerable thicknesses of subsequently formed sediment tends to maintain the gypsum as such, for there is an increase of volume in the transformation gypsum → anhydrite + water, and although the liquid phase will at once seek regions of lower pressure, it is the volume relationships at the moment of transformation that regulates transformation conditions.

In the opinion of the writer, the anhydrite in the Upper Silurian of Manitoba is primary, and the order gypsum–anhydrite–gypsum represents the mineralogical sequence of deposition in Upper Silurian times. The presence of gypsum underneath the anhydrite is rather conclusive evidence against the secondary character of the anhydrite zone. With regard to the upper gypsum, there has unquestionably been a certain amount of transformation into gypsum of the top beds of the anhydrite since Tertiary times. Analyses of the upper anhydrite beds show a continuously increasing water value from the middle of each bed to the margin, an evidence that a gradual change is taking place. Besides, the folded structure of the gypsum beds is most naturally explained as a 'Gekröse'[2] phenomenon, due to an internal increase of volume in the solid phase, consequent on transformation. It is believed, however, that only the lowest beds of the upper gypsum have so originated, and that the internal pressure has been transmitted to the overlying gypsum, which had been precipitated as such at a late stage of the evaporation.

[1] J. M. Bell, Geological Survey of Canada, 1899, xii, 25 C.
[2] Koken, *Zentralb. f. Min.*, u.s.w., 1902, 3.

The physical conditions would seem to have been somewhat as follows:—Owing to elevation in late Niagara times, the sea withdrew towards the north, and an inland arm of the northern sea was placed in imperfect communication with the outer ocean. Chemical precipitation of the carbonates took place, followed by deposition of the sulphates as gypsum. Later, communication with the ocean closed, the temperature of the waters of the basin rose, and anhydrite began to form. At a still later stage lower temperatures prevailed, probably because of the entrance of ocean waters, and continuous deposition of gypsum ensued. The concentration of sodium salts became so great that part of the sodium ions was precipitated in the form of double sulphate. It is still an open question whether evaporation reached the stage of the deposition of the chlorides. When, finally, deeper-water conditions again prevailed, carbonates and traces of sulphates were thrown down, and formed the limestone which now represents the highest beds of the Silurian in Manitoba.

To summarize, the following conclusion of general applicability may perhaps be legitimately derived from the study of a particular gypsum–anhydrite association. While secondary transformations are possible at considerable depths, and also at the surface, the general character of gypsum–anhydrite deposits may be accounted for most directly, and with least difficulty, as due to original deposition. This applies most obviously in cases where the bedding-plane defines with fair accuracy the contact between anhydrite and gypsum. Where anhydrite occurs in masses irregularly distributed through gypsum rock, transformation processes at or near the surface have played a relatively greater part; but direct geological evidence has yet to be adduced before the theory can be accepted that transformation of gypsum to anhydrite, at great depths below the surface, takes place to such an extent as to be of geological importance.

REVIEWS.

I.—Memoirs of the Geological Survey of Scotland. Geology of Central Ross-shire (Explanation of Sheet 82). By B. N. Peach, LL.D., F.R.S., John Horne, LL.D., F.R.S., and others; with Petrological Notes by J. S. Flett, D.Sc., LL.D., F.R.S. 8vo; pp. vi, 114. Edinburgh, (1913) 1914. London: T. Fisher Unwin, 1 Adelphi Terrace, W.C. Memoir, 2*s.* 3*d.*; map, 2*s.* 6*d.*

The area included in Sheet 82 is approximately 429½ square miles in extent; about 2½ square miles of salt water at the head of Loch Carron enter into the limits of the map. With the exception of a small part of Inverness-shire in the south-east corner, on either side of Glen Strath Farrar, the whole map falls within the County of Ross.

This is a typical Highland area, in which cultivation and population are reduced to a minimum and confined to the seaboard and a few spots along the larger river-valleys. The ground is mountainous, wild, and inaccessible, and is given up to deer forest and grouse moor, with small and decreasing areas of sheep-grazing at Kinlochewe, Loch Carron, and Scardroy.

The mean annual rainfall exceeds 60 inches, while at Loch Torridon and Glen Carron, situated in narrow glens among lofty mountains, the average fall is respectively 88·58 and 90·23 inches, and at the latter station has reached as high as 109 inches for one year.

This tract of country may be described as a more or less denuded high mountain plateau, falling towards the north-east and reaching its greatest elevation along a line drawn from Beinn Eighe, in the north-west corner of the map, to An Riabhachan and Sgùrr na Lapaich on the southern margin. The most obvious features in the surface-relief are the three through-valleys which cross the region in a nearly parallel E.N.E.–W.S.W. direction.

Ten rivers and eight lakes (or lochs) bespeak the abundant rainfall of the district, while Loch Torridon and Loch Carron, the heads of fiords, are obviously the seaward extension of drowned valleys pre-glacial in origin and formed when the land stood at a higher level than at the present time. Subsequent glacial erosion produced over-deepening of the valleys and excavated a succession of rock-basins, now all beneath sea-level, in their floor, but they were in all probability partly eroded below the present sea-level before the glaciation of the country. After the disappearance of the ice from the lower part of the valleys, moraines, fluvio-glacial gravels, raised beaches, and river alluvia were left behind very generally, partially filling up many of the lochs with moraine deposits.

Turning to the solid geology depicted on the map, one is struck by the great antiquity of the rock-groups which form the entire area. Thus "The whole of the ground east of the River Carron and of a line drawn from Achnashellach to Kinlochewe is occupied by crystalline metamorphic rocks—the siliceous and perlitic schists of the Moine Series—surrounding inliers of complex gneisses of Lewisian type. The latter are most widely developed in the eastern part of the area, where the largest inlier is found in the basin of the Meig, and forms a great part of the mountain Sgùrr a' Ghlas Leathaid. Other smaller masses occur in Glen Orrin, in Glen Strath Farrar, and round the head of Loch Monar. These inliers are all east of the 'Moine thrust'.

"Another large mass of Lewisian Gneiss enters the map on either side of Loch Carron, and is continued as a narrow and interrupted belt along the west side of Strath Carron, and northwards through the Coulin Forest to within a short distance of Kinlochewe. This western belt forms part of the thrust masses situated west of the Moine thrust; the portion south of Loch Carron lies to the east of that line of movement. A portion of a small inlier of unmoved Lewisian rocks appears on the western margin of the map 2½ miles north of the head of Loch Torridon.

"The remaining north-western portion of the sheet is occupied by sedimentary rocks of Cambrian and Torridonian age, these two formations alternating in parallel belts along lines of thrust or natural outcrop; while, in the unmoved area, the Cambrian quartzites cap the highest peaks of Laithach and Beinn Eighe" (p. 10).

Sixty-four pages (chapters iii to viii) are occupied with a detailed account of the Moine thrust and its effect upon the tectonics of the area in relation to the Lewisian Gneiss, the Torridonian Sandstones and Cambrian strata. The description is aided by a series of sections: (1) from Laithach by Sgùrr Dubh to the River Coulin (p. 20); (2) from Beinn Damh across Chinn Deirg to Coulags, Strath Carron (p. 23); (3) from Strath a' Bhathaich by Glas Bheinn to Kirkton on Loch Carron (p. 24); (4) diagrammatic sections, showing the relations of the Moine Series to the Lewisian Gneiss south of Attadale, Loch Carron. The areas west and east of the Moine thrust and the inliers of Lewisian Gneiss and their petrography are described. Then follows a detailed account of the Moine Series between Glen Carron and Glen Docherty; the Monar area, the valley of the Meig, Glen Orrin, Glen Strath Farrar; and Glen Cannich. The elucidation of these very disturbed and complex districts is greatly assisted by a small map (fig. 5, p. 59) of the Beinn Dronaig area and a diagrammatic section (fig. 6, p. 70) across the northern region from Kinlochewe to the River Meig, showing the massive siliceous granulites, the flaggy siliceous schists, the pelitic gneiss and lower siliceous schists of the Moine Series, and the Applecross and Diabaig Groups and Lewisian Gneiss of the Torridonian Series which are affected by them. Fossils are hardly to be expected in such highly altered, squeezed, and contorted strata, but Fucoid Beds are recognized by Dr. Horne and "*Salterella* (Serpulite) Grits are traceable through parts of the Coulin and Achnashellach Forests, where they are reduplicated in places by folding and reversed faults. Of special importance is the occurrence in the Fucoid Beds of a band of pisolitic ironstone, from 18 inches to 2 feet thick, in the Allt nan Dearcag, one of the sources of the Coulin River, about 2 miles north from Achnashellach station. There can be no doubt that it represents the layer of pisolitic ironstone in the same subgroup on the northern slopes of Meall a' Ghiubhais which yielded to Mr. Macconochie remains of Trilobites and Echinoderms. The band at Allt nan Dearcag contains *Hyolithes*, and under the microscope plates of *Eocystites* and fragments of the tests of Trilobites have been observed" (p. 18).

In the Bibliographical Appendix of works relating to the geology of the district a paper has accidentally been omitted. It is: 1880, Hicks, Henry, and Davies, T., "Pre-Cambrian Rocks of West and Central Ross-shire," Geol. Mag., 1880, pp. 103, 155, 222, 266, and 329.

Eight excellent collotype plates illustrate the most important points in the scenery of Ross-shire and ten text-figures.

II.—The Geology of the Country near Fareham and Havant. By H. J. Osborne White, F.G.S. pp. 96. 1913. Price 1*s.* 9*d.*; map 1*s.* 6*d.*

THIS Memoir is an explanation of Sheet 316 of the Geological Maps on the scale of 1 inch to the mile, surveyed on the 6 in. scale by Messrs. W. Whitaker, C. Reid, and C. E. Hawkins. The district dealt with is situated for the most part in the south-east of Hampshire, the remainder in South-Western Sussex. There are only four small towns in the area, Fareham, Havant, and Emsworth in the south and Bishop's Waltham in the north-west.

The western end of the South Downs runs through the northern part of the district. To the north of this ridge the Gault and Lower Greensand come on in the Wealden area near Petersfield. To the south the ground slopes gently to the wooded track of the Forest of Bere on Eocene strata. Southward again from this tract comes the Chalk ridge of Portsdown, which declines eastward and westward from a point above 400 feet near Southwick.

The lowest strata exposed in the district are the Sandgate Beds, which occur near the north-eastern corner and are believed to be about 70 feet thick. The succeeding Folkestone Beds here consist of yellow and white sands, with seams of carstone near the middle; they are not known to be fossiliferous, their thickness is locally about 150 feet. The Selbornian, comprising the Gault and Upper Greensand, is grouped under zonal headings, and most of the local Gault clays are considered to belong to the zone of *Hoplites interruptus*. The Greensand immediately below the Chalk is not well exposed; it was not seen eastward of Barrow Hill within the present district, but it may be continuous with the similar deposit observed south of Petworth.

Four chapters are devoted to a consideration of the Chalk. This formation occupies rather more than half the country, and probably attains a thickness of 1,200 feet in the southern part of the district, where it is most fully developed. The junction of the Upper and Middle Chalk is somewhat difficult to trace in the field, as there is no hard band of Chalk Rock at this horizon as in other districts. The line on the map has been drawn at the base of the markedly flint-bearing beds or rather below the actual top of the Middle Chalk. The generally accepted zones of the English Chalk have been recognized, and due note is taken of the recent work of Messrs. Griffith and Brydone.

With regard to the Lower Chalk, this is confined to the northern part of the area. Its lowest member, the so-called Chloritic Marl, is about 3 feet thick; this is followed by bluish marls belonging to the zone of *Schloenbachia varians*; the succeeding zone of *Holaster subglobosus* is composed of yellowish-white chalk. The top of the Lower Chalk is plainly marked by the *Actinocamax plenus* Marls. The thickness of the Lower Chalk is estimated at 220 feet.

In the Middle Chalk the Melbourn Rock appears to be represented by a bed of firm sub-nodular white chalk, 2 to 4 feet thick at the base of the *Cuvieri* zone, which here consists of alternations of lumpy white chalk and of thinner roughly laminated marly chalk. The zone is about 70 feet thick. The *Terebratulina lata* zone consists mainly of white chalk with some thin seams of grey marl, and contains a good number of small flints. It is about 120 to 130 feet thick. The total thickness of Middle Chalk is about 200 feet.

The Upper Chalk in the southern part of the district is probably about 750 feet thick. It here comprises six zones, from *Holaster planus* to *Belemnitella mucronata* inclusive. The greater part of the last-named zone is, however, missing, owing to erosion in early Eocene times. The zone of *Holaster planus* is composed of distinctly nodular chalk; flints are common, small, and with thick rinds. The sub-zone of *Heteroceras reussianum* has not been recognized, and the Chalk Rock often developed at that horizon is wanting. Little is seen of the zone of *Micraster cor-testudinarium.* Mr. Brydone's estimate of the combined thickness of the *Cor-testudinarium* and *planus* zones at Warnford is 112 feet. The zone of *Micraster cor-anguinum* is 226 feet thick at Warnford, and consists mainly of soft white chalk with abundant flints. There are few exposures, as is also the case in the *Marsupites testudinarius* zone. The chalk of this zone is very soft and contains few flints. The *Uintacrinus* and *Marsupites* bands are both recognizable, and each is probably about 35 to 40 feet thick. The zones of *Actinocamax quadratus* and *Belemnitella mucronata* are well exposed. The former is about 300 feet thick; in its lower part it is soft white chalk very similar to that of the underlying zone; it becomes gradually more marly and contains an increasing number of flints towards the top; all the exposures of consequence are in Portsdown. Details are given of the subdivisions of this zone advocated by Messrs. Griffith and Brydone. The zone of *Belemnitella mucronata* is well developed near Fareham, where there appears to be a thickness of about 60 to 70 feet.

The Memoir deals in detail with the various exposures of the several zones, and an extensive zonal list of fossils is given. The junction of the Cretaceous with the Eocene beds is nowhere clearly shown, but their unconformability is proved by the relations of their outcrops in different parts of the district. The *mucronata* beds of Portsdown have nowhere been observed along the northern boundary of the Eocene strata between Upham and Funtington. This discordance is part of a widespread unconformity which takes the form of an overstep of the Cretaceous by the Eocene in a northward direction; thus more than half the Upper Chalk is cut out in the distance of 50 miles between the Isle of Wight and the Berkshire Downs.

The Eocene beds immediately overlying the Chalk belong to the Reading Series; the seams of glauconitic sand which are common in other areas are found to be wanting, as also are the commonly associated oyster-shells and fish-teeth. The bulk of the formation consists of clays and loams. The average thickness is estimated at about 110 feet. Notes are given of exposures in both the northern and southern outcrop.

The thickness of the London Clay is given at about 250 feet. It is made up of evenly stratified silty clays, loams, and loamy sand, with thin beds or seams of impure shelly limestone and of flint pebbles.

Details of sections are given and a list of fossils from the Catisfield cutting and from Fareham Station. Short chapters deal with the Bagshot Sands and Bracklesham Beds; the thickness of both varies considerably. A chapter on Tectonic Structure and Land Forms is of considerable interest. It is considered that during the Eocene and Oligocene periods the eastern part of the Hampshire Basin never rose much above sea-level, the main folds being developed in Miocene times, and the various folds and faults are discussed in detail. A few interesting points in connexion with the drainage of the country are also brought forward. A number of unstratified superficial deposits are grouped under the heading of Clay-with-Flints;

they are considered to be a product of the disintegration of the Tertiary beds and the Chalk, and are assigned to the subaërial class. Their relation to the solid formation is discussed.

The remaining superficial deposits—raised beach, gravels, and brickearth—have apparently all been laid down in water. Two small patches of raised beach are mentioned, which rest a little below 100 feet O.D. Plateau gravels rest in patches on the Eocene beds at altitudes between 30 and 315 feet; they are considered to be mainly old river-deposits, and the various types are dealt with in detail. The Valley Gravels are often chalky, when they are known as Combe Rock; they occur in all the principal valleys, and in this connexion mention is made of the sheet of chalk and flint rubble which clothes the southern slope of Portsdown. The brickearth is a brown loam which thinly cloaks the edges of the Chalk and Eocene on the lower steps of the coastal plain.

In dealing with the Alluvium it is pointed out that by the close of the Pleistocene period the larger rivers were running in valleys cut down, through the gravel and brickearth-covered flats of the coastal plain, to a depth of perhaps 20 or 30 feet below the ordinary high-tide level of the present day, the coastline lying then farther to the south. Subsidence has allowed the sea to advance once more northward, drowning the lower reaches of the valleys, and filling them with alluvial deposits. The mud and associated deposits are said to attain a thickness of 35 feet at the Docks in Portsmouth Harbour (south of the district).

A chapter on economic aspects of the geology, including notes on the water-supply, concludes the memoir.

III.—Tertiary Echinoids of the Carrizo Creek Region in the Colorado Desert. By William S. W. Kew. University of California Publications: Geology, Vol. VIII, No. 5, pp. 39–60, pls. i–v. Berkeley, April 16, 1914.

THE Echinoid fauna of North America is known through a seriously disjointed record. The marvellous profusion of Palæozoic forms cannot be matched in any other country, but Mesozoic types are practically negligible. It is not until the later Tertiary stages are reached that the history of Echinoid evolution is resumed, and then in a few coastal regions only. Much of our knowledge of the fauna of these relics of Tertiary subsidence is due to work carried out under the auspices of the University of California. Hence it is that the regions bordering on the Gulf of California have given almost the only evidence of American Cainozoic Echinoids. In view of the extreme wealth of existing Echinoderm life in the shore waters of the area, the study of the corresponding forms of a time not long past has a peculiar interest.

The age of the Carrizo formation, the horizon of the Echinoids described in the paper under review, has not been precisely determined. It has been correlated with the Etchegoin Series (of Upper Miocene or Lower Pliocene age), but, as the writer indicates, the Echinoid fauna is so nearly akin to the existing one of the neighbourhood that an even later date is possible. In this connexion it is interesting to note that the affinities of the known fauna of the Carrizo formation are definitely with that of the Gulf of California, and have no apparent relation to that of the Pacific region—an indication that the Peninsular Mountains then, as now, formed a continuous barrier between the two districts.

The Carrizo Series is divided into two sections, from the lower of which all the Echinoids have been exclusively collected. The upper part of the series seems to have been formed under brackish conditions, during the gradual silting-up of the Gulf. The lower series exhibits two facies—a littoral zone of reddish conglomerate and arkose, and an outer zone, reaching as much as 50 fathoms in depth, represented by finer sediments. It is interesting to find that the species of Echinoids that predominate in one type of deposit are rare or absent in the other, although representatives of the same genera are abundant in both.

One species of *Hipponoë*, three of *Clypeaster*, one of *Encope*, and an indeterminable specimen of *Cidaris* are described. All but one of the species are new, but the impression left by a perusal of the text and a study of the plates is that their chief claim to novelty lies in their fossil condition. There seems to be something akin to the point of view of a century ago in the specific separation of recent and fossil types in spite of their resemblances. In every case but one the species described are admitted to differ from the existing forms of the district in mere details of size and proportion. That they are ancestral to the species of the present day seems clear, but it seems doubtful whether, in the majority of cases, their ancestral characters render them sufficiently distinct for more than varietal separation.

Perhaps the most interesting of the forms described is *Encope tenuis*, which is practically identical with the recent *E. californica*, but has the radial lunules of the latter species represented by the primitive condition of marginal notches. *Clypeaster carrizoensis*, the species whose living representative is unknown, appears from the figure to be more nearly related to *Laganum* than to *Clypeaster*.

It is greatly to be hoped that further researches may be made into the fauna of the Carrizo formation, and that thereby the history of the peculiar and teeming fauna of the Gulf of California may be more fully written. In the meantime this paper should be of value as showing the possibilities underlying such research in the solution of problems of both biological and geographical interest.

H. L. H.

IV.—Geology of the Strata traversed by the D'Urban Artesian Well Boring, 1913. By Professor J. B. Harrison, M.A., C.M.G. pp. 18. British Guiana Combined Court, Annual Session, 1914.

PREVIOUS well-borings in British Guiana appear to have tapped water derived from beds of sand at less than 200 feet below the surface. These sands were thought to be stratified beds, but they are now shown to be more or less lenticular masses of wind-blown sand:

the water derived from them was either ferruginous or saline, and the supply was not continuous.

The present boring passed through 178 feet of alluvial deposits, resting on a considerable thickness of dune sand, which yields highly ferruginous water. Below 280 feet the beds are estuarine and marine in character, and these continue until granitic rocks, presumed to be Archæan, are reached at 579 feet. These formations supply evidence of a depression of the granitic rocks to a depth of not less than 280 feet. The dune sands mark an elevation or cessation of movement, and indicate a long period of rest followed by a further depression, during which the upper alluvial deposits were formed.

Water was found at nine levels, but the only good drinking-water was yielded by two beds of sand immediately above the granitic rocks. This water is derived from the thick lateritic and lithomargic deposits which rest on a floor of igneous rocks in the high lands of the colony. The water from the lowest level contains only 5·3 grains of solid in solution per gallon and has a temperature of 90·4° F. The mean daily flow from August 25 to November 27 was 198,000 gallons. Analyses are given of the water obtained from nine different levels in the boring.

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *April* 8, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Evolution of the Essex River System, and its Relation to that of the Midlands." By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

The post-Eocene geology of Essex must be learnt from its gravels and their non-local constituents. In the absence of any rock which affords a certain proof of its route, the effort was made to determine the direction of transport by tracing the variations in the proportions and size of the non-local constituents. This test shows that the quartzites and felsites came from the north-west and the Lower Greensand cherts from the south and south-east.

A. The gravels may be classified as follows:—

(1) The oldest series. The Brentwood group, which consists of redeposited Bagshot Beds and of local materials only.

(2) The Danbury Gravel, which was deposited before the arrival of the felsites, and at the beginning of the arrival of the Lower Greensand cherts.

(3) The Braintree Gravel, which is largely composed of quartzitic drift, with abundant Lower Greensand cherts and some felsites that were probably derived from the Lower Greensand conglomerates north-west of Essex.

(4) and (5) Glacial and post-Glacial gravels.

B. Judged from the distribution and dates of appearance of the non-local constituents in these gravels, the evolution of the Essex river systems appears to have been as follows:—

(1) The Thames-Kennet River was formed along the axis of the syncline of the Thames Basin. The Thames, therefore, began its existence in the Upper Eocene and Oligocene periods, and then flowed north-eastwards and passed out of Essex to the north of Clacton. Tributaries down the northern slope of this syncline introduced the quartzite-drift from the Midlands, while flints from the Chalk were washed down both slopes.

(2) As denudation lowered the upraised borders of the Thames Basin, the Lower Greensand was exposed in the North Downs, and chert from it was carried into Essex. The chert began to reach Mid-Essex after the deposition of the Brentwood Gravels (probably Upper Eocene) and during the deposition of the higher-level Danbury Gravels (360 feet). As the Upper Greensand had been exposed in the Weald during the Lower Eocene period, it is most probable that the Lower Greensand would have been exposed during the Oligocene period. Its exposure in the Miocene period is indicated by the occurrence of its cherts in the crags, combined with the existence of a plain in Northern Kent before the oldest Pliocene (Diestian). As the oldest Danbury Gravels give no evidence of redeposition they are, at the latest, Miocene.

(3) Further denudation exposed the Lower Greensand conglomerates of Cambridgeshire, and felsites from them were carried into Mid-Essex, where they arrived later than the highest-level Danbury Gravel, but during the deposition of the Braintree Gravel on an old plain, at about 200 feet above the present sea-level. The Braintree Gravels were not later than the end of the Miocene period, although many of them have probably been redeposited in the Pliocene.

(4) The Upper Miocene, or at least pre-Diestian, earth-movements lowered the Weald, and led to the deposition of the Diestian Sands on the worn-down northern edge of the Wealden anticline. This subsidence deflected the Thames southwards to its present line. Its former route was closed by the uplift of Mid-Essex by the reversed fault or fold along the Mid-Essex Range. The latest date for this movement is indefinite. It has been suggested that the great height of the Danbury Gravels is due to uplift. The most definite evidence as to the age of the earth-movement shows that it was later than the existence of the Blackwater and Chelmer Rivers. These rivers, after the diversion of the Thames to its present line, must have extended their old valleys south-eastwards; the Blackwater and the Colne excavated the estuary of the Blackwater, and the Chelmer, following a parallel route, discharged through the Crouch. These rivers and most of the larger Essex river valleys were pre-Glacial, but the smaller valleys in Northern, Central, and Western Essex were completely filled during Glacial times, and so the streams, such as the Upper Roding, have had to excavate post-Glacial valleys.

(5) A post-Glacial change led to the deepening of the Chelmer Valley between Chelmsford and Maldon, whereby the Chelmer was

diverted to the Blackwater and the Crouch left as a beheaded estuary or föhrde.

(6) The Lower Thames and Essex river systems are therefore due to the Eocene earth-movements which formed the London Basin, and the coeval uplift of the English Midlands started thence a radial drainage. The streams to the south-east cut the wind-gaps on the Chiltern Hills, and the drainage to the south-west flowed along a subsidence on the north-western side of the Jurassic escarpment as the Warwickshire Avon and the Lower Severn.

2. "The Topaz-bearing Rocks of Gunong Bakau (Federated Malay States)." By John Brooke Scrivenor, M.A., F.G.S.

Gunong Bakau is a peak, 4,426 feet high, in the main range of the Malay Peninsula. It is composed of porphyritic granite, into which have been intruded veins of quartz-topaz rock, and, at a later date, masses and veins of topaz-aplite.

The quartz-topaz rock has quartz and topaz as constant constituents. Other important constituents, which, however, are not always found, are cassiterite, zinnwaldite rich in iron and showing the axial figure of a uniaxial mineral, and tourmaline. The zinnwaldite is only known to occur in quantity in one vein: elsewhere it is sometimes found forming patches in the quartz-topaz rock.

The topaz-aplite contains a small amount of cassiterite.

Where the quartz-topaz veins cut the granite a 'reaction border' of schorl-rock, and, in one case, of greisen, is found. These reaction borders differ widely from the veins themselves.

Evidence is given in detail, showing that the quartz-topaz vein-rock is not an alteration product of a pre-existing rock, but was intruded as a quartz-topaz magma.

Ore-bodies formed by pneumatolytic alteration of granitic rocks were once worked on Gunong Bakau, and they differed markedly from the quartz-topaz rock.

It is believed that the difference between the familiar pneumatolytic products, schorl-rock, and greisen, on the one hand, and the quartz-topaz rock on the other, is that, in the former case, rocks that had consolidated on the edge of a granite-mass were altered by media coming from deeper parts of the mass; whereas, in the latter, an accumulation of similar media attacked part of the still molten magma deep down in the igneous mass, and the heat generated by the reactions that took place caused the portion of the magma attacked to boil up and consolidate in the granite as an intrusive vein-rock. Segregation of the first-formed minerals during cooling led to the irregular distribution of the constituent minerals in the veins.

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2. *April* 29, 1914.—Dr. A. Smith Woodward, F.R.S., President, and afterwards, William Hill, Vice-President, in the Chair.

The following communications were read:—

1. "On the Lower Jaw of an Anthropoid Ape (*Dryopithecus*) from the Upper Miocene of Lérida (Spain)." By Arthur Smith Woodward, LL.D., F.R.S., Pres.G.S.

The author describes and discusses the greater part of a mandibular ramus and symphysis of *Dryopithecus fontani*, lent to him by Professor L. M. Vidal, of Barcelona. The specimen was found by Señor José Colominas in association with the *Hipparion* fauna at Seo de Urgel, in the Province of Lérida (Northern Spain). It is, therefore, the latest jaw of an Anthropoid ape hitherto discovered in Europe, although probably contemporaneous with the isolated Anthropoid teeth from the Bohnerz of Würtemburg and the well-known Anthropoid femur from the Sands of Eppelsheim (Hesse-Darmstadt). The relatively small size of the first molar is to be regarded as a primitive character, lost in all modern Anthropoids except some Gibbons. The shape of the mandibular symphysis is almost remarkably primitive, with the surface of insertion for the digastric muscle nearly as large as that of the ancestral Macaques (for instance, *Mesopithecus*). The anterior face of the symphysis slopes directly upwards from the front edge of this insertion, as in the Macaques, some Gibbons, and very young individuals of the Chimpanzee, Gorilla, and Orang. It thus differs considerably from the mandibular symphysis in adult individuals of these existing Apes, in which the lower portion of the slope curves backwards into a more or less well-defined flange or shelf of bone, while the digastric insertion is reduced in extent. The mandibular symphysis of *Dryopithecus* is, indeed, intermediate in shape between that of the Upper Miocene or Lower Pliocene *Mesopithecus* and the Lower Pleistocene *Homo heidelbergensis*. So far as its lower jaw is concerned, *Dryopithecus* is, therefore, a generalized form from which modern Anthropoid apes and man may have diverged in two different directions.

2. "The Structure of the Carlisle-Solway Basin, and the Sequence of its Permian and Triassic Rocks." By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

The Carlisle-Solway basin has been generally represented as a syncline, with the Solway resting on a great thickness of Triassic rocks. A boring made near Gretna in 1794 shows, on the contrary, that Lower Carboniferous rocks crop out there at the surface. This boring shows that the basin is not a simple syncline.

The evidence derived from the boring necessitates reconsideration of the Permo-Triassic sequence in North Cumberland, as to which the Geological Survey maps and memoirs are not in agreement. According to Mr. Holmes's view, expressed in the memoir, there are two series of gypseous shales, one above and the other below the St. Bees Sandstone. According to the classification adopted on the maps, there is only one horizon of gypseous shales, which is below the St. Bees Sandstone. Mr. Holmes's case rests on the identification of the rock at the bottom of the Abbeytown boring as St. Bees Sandstone. If that rock be accepted as the Penrith Sandstone, it is unnecessary to assume two series of gypseous shales. Arguments are given to show that the evidence for the existence of the St. Bees Sandstone at the bottom of the Abbeytown and Bowness borings is quite inconclusive, and the fact is improbable. The view adopted by the Geological Survey map as the alternative to Mr. Holmes's conclusion, that the area west and north-west of Carlisle consists of Keuper deposits, is also improbable, the rocks thus identified being the gypseous shales above the Penrith Sandstone.

CORRESPONDENCE.

THE CARLISLE-SOLWAY BASIN.

Sir,—In the discussion on the Carlisle-Solway basin at the Geological Society (Abstr. Proc., No. 958) I omitted to reply to Mr. Lamplugh's argument that the Point of Ayre bore in the Isle of Man supports the identification of the rock at the bottom of the Abbeytown bore as the St. Bees Sandstone. The correlation on which this view is based does not seem to me supported by the evidence. The Point of Ayre bore has been recorded in detail by Mr. Lamplugh (Isle of Man memoir, 1903, pp. 585–6), and he there classed the beds above the St. Bees Sandstone as the "Saliferous Marls" and obviously regarded them as Keuper (ibid., p. 291). Mr. Lamplugh's argument depends upon the correlation of these beds with the Gypseous Shales at Abbeytown. As no specimens of the rocks from these bores are available, we can only compare them by the bore records. The following table summarizes the records:—

	Abbeytown. Times mentioned.	Point of Ayre. Times mentioned.
Beds—		
Shale	61	0
Micaceous Shale	1	0
Sandy Shale	10	0
Marl	0	36
Sandy Marl	0	3
Marlstone	0	19
Sandstones	6	4
Breccia	0	1
Minerals—		
Salt in beds	0	18
Salt in shale	1	0
Salt in marl and marlstone	0	27
Gypsum	36	18
Colours—		
Red	54	0
Brown	0	42
Green	17	0
Blue	20	11
Purple	1	0
Grey	8	22
White	8	0
Thickness	79 beds, average 10′ 5″	80 beds, average 6′ 2″

The two series agree in being argillaceous members of the red rock series, but the differences between the two sets of rocks seem far greater than the resemblances. They both contain some gypsum and salt. But the only salt recorded in the Abbeytown journal is present in a 5 ft. layer of red shale with gypsum and salt. In the Point of Ayre bore the salt occurred in eighteen beds, which yielded 76 ft. 8 in. of cores of salt, in addition to numerous salt-bearing marls.

No doubt the descriptions in bore journals have to be interpreted freely, but the differences in the above descriptions can hardly be thus dismissed. The original assignments in the Survey Memoirs of the two series of beds to different systems appear both to have been correct. Mr. Lamplugh was probably right in identifying the Isle of Man beds as Triassic saliferous marls and Mr. Holmes in identifying the Abbeytown beds as Permian Gypseous Shales. Why correlate the beds at Abbeytown with such different beds over 50 miles distant, while similar rocks occur only 16 miles away? If the identifications in the Isle of Man and Carlisle memoirs be correct, then the salt-bearing marls of the Isle of Man belong to a different system from the Gypseous Shales of Abbeytown, and the red sandstone below the two sets of beds is probably also of different age. The fact that the sandstone below the Keuper marls in the Isle of Man is the St. Bees Sandstone is an additional reason why the sandstone below the Permian Gypseous Shales at Abbeytown is not the St. Bees Sandstone.

J. W. Gregory.

Geological Department,
University, Glasgow.
May 14, 1914.

OBITUARY.

EDUARD SUESS.

Born August 20, 1831. Died April 26, 1914.

It is with deep regret we record the death of our dear friend of long ago, Professor Eduard Suess, which occurred at Vienna on Sunday, April 26. It was so lately as in January of last year (Geol. Mag., 1913) that we published a brief notice with his portrait (Plate I) among our list of Eminent Living Geologists.

In 1851 he was appointed an Assistant in the Imperial Museum, Vienna, and in 1857 he was made Professor in the Vienna University. In 1862 he resigned his Museum work and devoted all his leisure, not occupied by his lectures in the University, to palæogeographical researches, culminating in his great work *Das Antlitz der Erde* (The Face of the Earth), Prag, Wien, Leipzig, 1883–1909. An English translation, from the Clarendon Press, Oxford, appeared in 1904, edited by Professor Sollas, the fourth volume of which was issued in 1909.

Sir Archibald Geikie writes of the French translation, edited by M. E. de Margerie (1897–1911), that it has been "so enriched with footnotes by its Editor as to become an invaluable work of reference for published papers in every department of the wide range of subjects of which it treats".

Professor Suess was a Foreign Member of the Royal Society and also of the Geological Society of London, and received the Copley Medal from the Royal Society in 1903, and was Wollaston Medallist of the Geological Society in 1896. "Scarcely any other investigator of modern times has influenced science so lastingly and deeply as Eduard Suess" (Steinmann).

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EDITED BY

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

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JULY, 1914.

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

No. VII.—JULY, 1914.

ORIGINAL ARTICLES.

I.—The Foraminifera of the Speeton Clay of Yorkshire.

By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S.

(PLATE XIX.)

(*Concluded from the June Number, p. 265.*)

Family ROTALIIDÆ.

Sub-family ROTALIINÆ.

Pulvinulina, Parker & Jones.

Pulvinulina repanda (Fichtel & Moll). (Pl. XIX, Fig. 14.)

Nautilus repandus, Fichtel & Moll, 1803: Test. Micr., p. 35, pl. iii, figs. *a, d.*
Pulvinulina repanda, Brady, 1884: Chall. Rep., vol. ix, p. 684, pl. civ, figs. 18*a–c*.

Remarks.—This species is recorded from the Tertiary formations of Italy by Parker & Jones and Seguenza, and is still living. Usually it occurs at depths less than 200 fathoms, but is known from 1,000 fathoms (Brady).

Horizon.—Found in B base *c*. Two specimens.

Pulvinulina caracolla (Roemer). (Pl. XIX, Fig. 15.)

Gyroidina caracolla, Roemer, 1840–1: Verst. n. d. Kreide, p. 97, pl. xv, fig. 22.
Rotalia caracolla, Reuss, 1862: Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 84, pl. x, fig. 6.
Pulvinulina caracolla, Chapman, 1897: Journ. Roy. Micr. Soc., p. 7, pl. i, figs. 9*a–c*.

Remarks.—The species is recorded from the Jurassic (Crick and Sherborn, Journ. Northants. Nat. Hist. Soc., vol. vii, p. 71, pl. vii (ii), figs. 26*a–c*, 1892) and from the Middle Hils and Speeton Clay of North Germany by Reuss. It is unknown in the Tertiary formation.

This is the most abundant species in the Speeton Clay of Yorkshire and the only Foraminifer that has been previously recorded from it. There are specimens named by Rupert Jones in the British Museum and the Museum of Practical Geology. Mr. Lamplugh refers to the occurrence of Foraminifera cemented together in small hard pellets (Q.J.G.S., vol. xlv, p. 596, 1889).

The numerous specimens show a considerable amount of variation. Some have the inferior surface greatly produced into a cone (Pl. XIX, Figs. 15*a*, *b*) with a mass of callus at the apex of the cone. The septa are very thick and the upper surface of the cells relatively thin, so that, when waterworn, a curious mulberry-like form is produced. Practically all the shells are more or less broken, and some of the specimens show the mode of arrangement of the earliest formed cells. Two varieties exist, microspheric and megalospheric forms respectively (Pl. XIX, Figs. 15*c*, *d*). The dimorphic condition of the allied *P. partschiana*, d'Orb. (*Rotalia pleurostomata*, Schlumb.), was noted by Schlumberger ("Sur le *Biloculina depressa*, d'Orb., au point de vu du dimorphisme des Foraminifères": Assoc. Française, Rouen, 1883 (1884), p. 526), who merely states that there is a great difference in the size of the initial cell in the two varieties of that species. In *P. caracolla* the initial cell in a microspheric shell has a diameter of about ·0088 mm., and in a megalospheric shell a diameter of ·055 mm., or about 6·25 times as much.

Certain specimens show an approach to *P. reticulata* (Reuss), but have not been separated from *P. caracolla*.

The depth at which *P. caracolla* lived is not known, as the species is extinct; but the strongly limbate group of *Pulvinulinæ* to which it belongs are now found at depths of from 70–1,000 fathoms (Brady, Chall. Rep.).

Horizon.—B base *b*, B base *c*, C_2, C_3, C_7, D_2 (base), D_2 (top), D_6. Very abundant.

Pulvinulina lamplughi, sp. nov. (Pl. XIX, Fig. 16.)

Description.—Test free, rotaliform, obtusely conical, the inferior surface nearly flat, the periphery acute and very slightly lobulated. Three convolutions, with usually five segments in the last. Sutures limbate, except the last. The cells, as viewed from the superior surface, are plano-convex, or very slightly concavo-convex in outline. The species belongs to the *P. elegans* group and is isomorphous with *Discorbina isabelleana* (d'Orb.). The nearest ally is *P. carpenteri*, Reuss. Width of test at widest about ·42 mm. (·017 in.). The depth from apex to base is about ·22 mm. (·0085 in.). I have named the species after Mr. G. W. Lamplugh, F.R.S., whose name will always be associated with the Speeton Clay.

Horizon.—Found in B base *c*, C_2, and C_3. One specimen in B base *c*, common in C_2 and C_3.

General Conclusions.

In all forty-four species (one of which has been only generically named, and will not, therefore, be further considered) and one variety have been recognized in the Speeton Clay. Of these, two species and the variety are new. Of the remaining forty-one species, twenty-three are still living, and seventeen of these are known from Jurassic or older deposits, one from the Lower Greensand, one from the Gault, and four from Tertiary deposits. Of the eighteen extinct species previously known, two range from the Jurassic to the Gault, but sixteen have only been found in Cretaceous strata. Including with these the two new species, it appears that eighteen, or 42 per cent, are Cretaceous only. Further, five species, or 11 per cent of the whole, are, so far as is known, confined to Lower Cretaceous beds.

Many species are represented by a single or very few specimens. If we consider not only the number of species but the number of individuals, it appears that the Speeton Clay of Yorkshire is characterized by the great abundance of *Pulvinulina caracolla* (Roemer), which is so plentiful that individuals of this species are probably at least as numerous as those of all the other species put together. Next in importance, numerically, is *Cristellaria rotulata* (Lamarck), a species which ranges from Jurassic to Recent times and has no stratigraphical value. The genus *Cristellaria* is relatively very abundant, and this genus is characteristically Cretaceous.

As the question of the Jurassic, or Cretaceous, age of the zone of *Belemnites lateralis*, Phil., is unsettled,[1] it is worthy of note that three of the seven species of Foraminifera from that zone are only known from Cretaceous rocks; the other four having a wide range in time.

The number of species in each genus represented in the Speeton Clay is given below, together with the corresponding figures for the Hils of Germany as given by Reuss (op. cit., p. 12). Reuss' classification and nomenclature have been modernized to enable the comparison to be more easily made.

Genus.	Speeton Clay of Yorkshire.	Hils of Germany.
Reophax	1	—
Haplophragmium	1	1
Ammodiscus	1	—
Textularia	1	1
Bigenerina	1	—
Gaudryina	1	—
Bulimina	1	—
Bolivina	—	1
Lagena	3	—
Nodosaria	9	12
Frondicularia	1	2
Rhabdogonium	1	4
Marginulina	4	7
Vaginulina	1	13
Cristellaria	13	22
Polymorphina	2	1
Amphimorphina	—	1
Dentalinopsis	—	1
Pulvinulina	3	1
	16 genera, 44 species.	13 genera, 67 species.

In both deposits *Cristellaria* is represented by more species than any other genus. The next best represented genus in the Hils, however, is *Vaginulina*, but in Yorkshire only a few fragments have been found, belonging to probably at least two species, although only one has been determined. *Nodosaria* is about equally well represented in both deposits, but it is remarkable that *Lagena*, which is fairly common in Yorkshire, has not been recorded from the Hils. Another noticeable difference is the presence of seven arenaceous genera in the Yorkshire Speeton Clay, as against two in the Hils.

Of the forty-four species from the Speeton Clay of Yorkshire, eleven, or 25 per cent, are known from the Hils of Germany. The presence at Speeton of *Rhabdogonium insigne*, Reuss, of the well-marked *Cristellaria gracillissima*, Reuss, both previously known only from the Upper Hils, and of *C. orbiculata* (Roemer), which Roemer described from the Speeton Clay of Germany, but which Reuss did not find, are interesting links between the deposits of the two countries.

[1] G. W. Lamplugh, "On the Subdivisions of the Speeton Clay": Q.J.G.S., vol. xlv, p. 589, 1889.

Compared with the Red Chalk of Speeton (described by Burrows, Sherborn, & Bailey), which is of the same age as the Gault, we find that fifteen out of forty-three species, or 35 per cent, occur in both deposits. If we compare the Speeton Clay with the Gault of Folkestone (described by F. Chapman) we find that twenty-five out of the forty-three species, or 58·5 per cent, occur also at Folkestone. Finally, comparing the Speeton Clay with the Bargate Beds of Surrey, described by Chapman, and of Lower Cretaceous age, there are seventeen out of forty-three species, or 40 per cent in common.

The fact that a higher percentage of species found in the Speeton Clay occurs in the Gault of Folkestone than in the Lower Cretaceous of Germany or Surrey, is to some extent, at least, due to the much greater abundance of Foraminifera in the Gault.

Little can be learnt from the Foraminifera as to the depths of the sea in which the Speeton Clay was laid down. At two horizons only are the species sufficiently numerous to throw any light on this question. Of the thirteen species from B (base) which are still living, four are at present found in water under 100 fathoms in depth. In the case of C_2, of the thirteen species which are still living five are at present found in water under 100 fathoms deep. The remaining species in each case are found in both shallow and deep seas.

Note.—A considerable number of the specimens are found to differ to a small extent from published figures of the species. These differences are too slight to justify varietal names, but in view of their presence it seems desirable to figure the species as found at Speeton. It is interesting to note that in Chalk forms which have been examined these differences are not found, showing that they represent real modifications of the types and are not due to imperfect drawings.

SUMMARY.

1. The Speeton Clay of Yorkshire contains abundant Foraminifera in the beds named by Mr. Lamplugh B (base), C_{10}, and C_2; but the specimens examined from the other subdivisions of F, E, D, and C either do not contain any Foraminifera or they are present in small numbers only.

2. Two new species, *Cristellaria chapmani*, *Pulvinulina lamplughi*, and a new variety, *Lagena apiculata*, var. *danfordi*, occur and are described. Forty-four species belonging to sixteen genera have been found.

3. The characteristic of the Foraminiferal fauna of the Speeton Clay is the great predominance of *Pulvinulina caracolla* (Roemer) over all other species.

4. Twenty-five per cent of the species of Foraminifera occur also in the Hils of North Germany, 35 per cent in the Red Chalk of Speeton, 40 per cent in the Bargate Beds of Surrey, and 58·5 per cent in the Gault of Folkestone.

5. Dimorphism is clearly shown by *P. caracolla* (Roemer). Previously it has been stated to occur among the *Pulvinulinæ* in *P. partschiana*, d'Orb., but no case has been described.

6. Notes are given on the microscopical characters of the sediments.

TABLE I.—Distribution of Foraminifera in the various subdivisions of the Speeton Clay of Yorkshire.

The presence of a species in any subdivision is indicated by the number of the species being placed in the corresponding column.

Species.	B base *b*.	B base *c*.	C_1.	Upper C_2 (?).	Upper C_3 (?).	C_7.	C_9.	C_{10}.	D_2.	D_3.	D_6 (mid).
1. *Reophax scorpiurus*, Montfort				1							
2. *Haplophragmium latidorsatum* (Bornemann)		2									
3. *Ammodiscus gordialis* (Jones & Parker)				3							
4. *Textularia agglutinans*, d'Orb.		4									
5. *Bigenerina nodosaria* (?), d'Orb.		5									
6. *Gaudryina filiformis*, Berthelin		6									
7. *Bulimina* sp.									7		
8. *Lagena globosa* (Montagu)			8	8				8			
9. *L. apiculata*, Reuss		9	9	9			? 9	9			
10. *L. apiculata*, var. *danfordi*, var. nov.				10							
11. *L. lævis* (Montagu)		11									
12. *Nodosaria (Glandulina) lævigata*, var. *strobilus*, Reuss								12			
13. *N. hispida*, d'Orb.	13										
14. *N. calomorpha*, Reuss		14									
15. *N. (Dentalina) siliqua* (?), Reuss		15									
16. *N. (D.) fontannesi*, Berthelin				16							
17. *N. (D.) lorneiana*, d'Orb.				17							
18. *N. (D.) legumen*, Reuss		18									
19. *N. (D.) communis*, d'Orb.				19							
20. *N. (D.) roemeri*, Neugeboren				20							
21. *Frondicularia gaultina* (?), Reuss				21							
22. *Rhabdogonium insigne*, Reuss											22
23. *Marginulina linearis*, Reuss				23							
24. *M. glabra*, d'Orb.		24									
25. *M. jonesi*, Reuss	25			25							25
26. *M. debilis*, Berthelin				26							
27. *Vaginulina incompta* (?), Reuss				27							
28. *Cristellaria gracillissima*, Reuss		28									
29. *C. acutauricularis* (Fichtel & Moll)		29	29								29
30. *C. gibba*, d'Orb.				30	30			30			
31. *C. cephalotes*, Reuss	31										
32. *C. scitula*, Berthelin		32									
33. *C. chapmani*, sp. nov.		33		33							
34. *C. crepidula* (Fichtel & Moll)		34		34							
35. *C. turgidula*, Reuss			35	35							
36. *C. cultrata* (Montfort)									? 36		36
37. *C. gaultina*, Berthelin		37									37
38. *C. sternalis*, Berthelin		38									
39. *C. orbiculata* (Roemer)		39									
40. *C. rotulata* (Lamarck)	40	40	40	40	40		40		? 40	40	40
41. *Polymorphina fusiformis*, Roemer		41		41							
42. *P. problema*, d'Orb.				42							
43. *Pulvinulina repanda* (Fichtel & Moll)		43									
44. *P. caracolla* (Roemer)	44	44		44	44	44			44		44
45. *P. lamplughi*, sp. nov.		45		45	45						

TABLE II.—DISTRIBUTION OF THE FORAMINIFERA OF THE

The presence of a species in any deposit is indicated by the

Species.	Range in time as previously known.
1. *Reophax scorpiurus*, Montfort	Jurassic–Recent
2. *Haplophragmium latidorsatum* (Bornemann)	Mid. Tertiary–Recent
3. *Ammodiscus gordialis* (Jones & Parker)	Carboniferous–Recent
4. *Textularia agglutinans*, d'Orb.	–Recent
5. *Bigenerina nodosaria*, d'Orb.	Miocene–Recent
6. *Gaudryina filiformis*, Berthelin	Gault–Recent
8. *Lagena globosa* (Montagu)	Oolite–Recent
9. *L. apiculata*, Reuss	Lias–Recent
11. *L. lævis* (Montagu)	Wenlock–Recent
12. *Nodosaria* (*Glandulina*) *lævigata*, d'Orb.	Jurassic–Tertiary
13. *N. hispida*, d'Orb.	Lias–Recent
14. *N. calomorpha*, Reuss	Tertiary–Recent
15. *N.* (*Dentalina*) *siliqua* (?), Reuss	L. Cretaceous–Chalk
16. *N.* (*D.*) *fontannesi*, Berthelin	L. Cretaceous–Gault
17. *N.* (*D.*) *lorneiana*, d'Orb.	Gault–Chalk
18. *N.* (*D.*) *legumen*, Reuss	Gault–Chalk
19. *N.* (*D.*) *communis*, d'Orb.	Permian–Recent
20. *N.* (*D.*) *roemeri*, Neugeboren (= *D. nana*, Reuss)	L. Cretaceous–Recent
21. *Frondicularia gaultina* (?), Reuss	Gault
22. *Rhabdogonium insigne*, Reuss	Lower Cretaceous
23. *Marginulina linearis*, Reuss	L. Cretaceous–Gault
24. *M. glabra*, d'Orb.	Rhætic–Recent
25. *M. jonesi*, Reuss	L. Cret.–Chalk Marl
26. *M. debilis*, Berthelin	L. Cretaceous–Gault
27. *Vaginulina incompta* (?), Reuss	Lower Cretaceous
28. *Cristellaria gracillissima*, Reuss	Lower Cretaceous
29. *C. acutauricularis* (Fichtel & Moll)	? Lias–Recent
30. *C. gibba*, d'Orb.	Lias–Recent
31. *C. cephalotes*, Reuss	Oxfordian–Gault
32. *C. scitula*, Berthelin	Gault
34. *C. crepidula* (Fichtel & Moll)	Lias–Recent
35. *C. turgidula*, Reuss (= *D. ingenua*, Reuss)	Gault
36. *C. cultrata* (Montfort)	Lias–Recent
37. *C. gaultina*, Berthelin (= *C. cultrata*, B., S., & B.)	Gault–Chalk
38. *C. sternalis*, Berthelin	Gault
39. *C. orbiculata* (Roemer)	Speeton Clay, Germany
40. *C. rotulata* (Lamarck)	Jurassic–Recent
41. *Polymorphina fusiformis*, Roemer (= *P. lactea*, B., S., & B.; = *P. prisca*, Berthelin)	Lias–Recent
42. *P. problema*, d'Orb.	Lias–Recent
43. *Pulvinulina repanda* (Fichtel & Moll)	Mid. Tertiary–Recent
44. *P. caracolla* (Roemer)	Lias–Gault

SPEETON CLAY OF YORKSHIRE IN SOME OTHER DEPOSITS.

number of the species being placed in the corresponding column.

Bargate Beds, Lower Cretaceous.	Germany.							Red Chalk, Speeton.	Gault, Folkestone.	Gault, Monte'ey, France.	*Challenger* Expedition.	Depth in fathoms now living.
	Middle Hils.	Upper Hils *a*.	Upper Hils *c*.	Speeton Clay.	*Tardefurcatus*-clay.	*Milletianus*-clay.	*Minimus*-clay.					
									1		1	any
									2		2	
3											3	50–2,000
4								4	4		4	
											5	7–1,630
6									6	6	6	to 620
8								8			8	any
9								9			9	any
11								11			11	any
								12			12	50–1,375
									13		13	95–450
								14			14	6–2,200
			15									
16									16	16		
							17		17			
									18	18		
								19	19		19	any
20			20		20		20		20	20	20	under 400
							21	21	21			
		22										
23							23		23	23		
							24	24	24		24	any
25		25							25	25		
26									26	26		
		27										
		28										
29											29	95–2,750
30			30	30				30	30		30	under 500
		31					31					
									32	32		
34		34				34		34	34		34	generally shallow to 2,350
						35	35		35	35		
36											36	rare under 100
								37	37	37		
									38	38		
				39								
40	40	40	40	40				40	40	40	40	any
			41				41	41	41	41	41	to 2,400
42								42	42	42	42	to 155
											43	to 1,000, usually under 200
	44			44					44			

EXPLANATION OF PLATE XIX.

All figures are magnified 50 diameters except Figs. 15*c* and 15*d*.

FIG. 1. *Cristellaria turgidula*, Reuss.
,, 2. *C. acutauricularis* (Fichtel & Moll).
,, 3. *C. sternalis*, Berthelin.
,, 4. *C. cultrata* (Montfort).
,, 5. *C. scitula*, Berthelin.
,, 6. *C. orbiculata* (Roemer).
,, 7*a*–*c*. *C. chapmani*, sp. nov. 7*a*, lateral aspect; 7*b*, the same differently illuminated; 7*c*, oral aspect.
,, 8. *C. crepidula* (Fichtel & Moll).
,, 9. *C. gibba*, d'Orb. 9*a*, lateral aspect; 9*b*, oral aspect.
,, 10. *Vaginulina incompta* (?), Reuss.
,, 11. *Frondicularia gaultina* (?), Reuss. Broken specimen.
,, 12. *Polymorphina fusiformis*, Roemer.
,, 13. *P. problema*, d'Orb.
,, 14. *Pulvinulina repanda* (Fichtel & Moll). 14*a*, superior aspect; 14*b*, inferior aspect.
,, 15. *P. caracolla* (Roemer). 15*a*, thin specimen; 15*b*, thick specimen; 15*c*, broken specimen showing megalospheric commencement, × 42; 15*d*, broken specimen showing microspheric commencement, × 42.
,, 16. *P. lamplughi*, sp. nov. 16*a*, superior aspect; 16*b*, inferior aspect; 16*c*, peripheral aspect.

II.—THE SGÙRR OF EIGG.

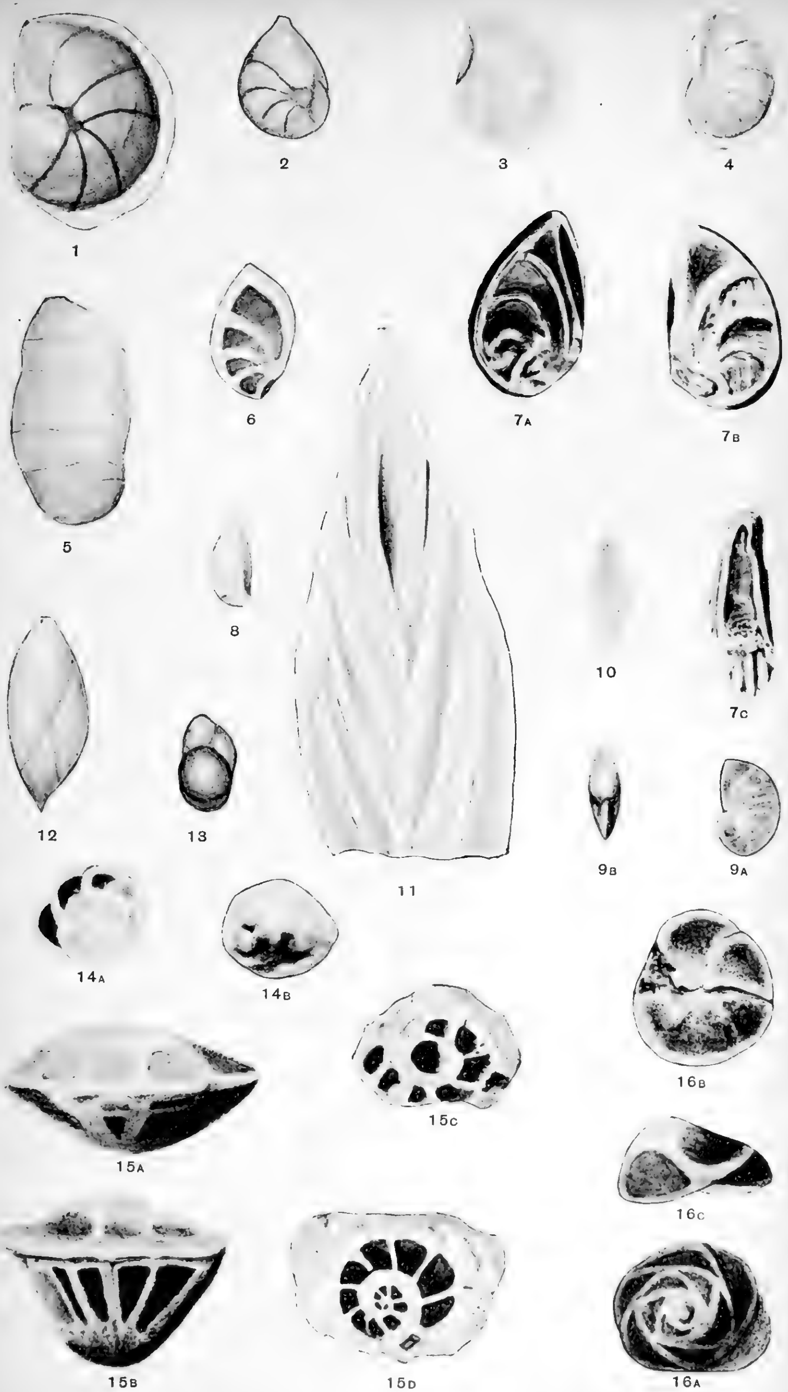
By E. B. BAILEY, B.A., F.G.S.

(PLATE XXII.)

THE Sgùrr of Eigg first attained to geological prominence in 1865, when Sir Archibald Geikie in his delightful account of the *Scenery of Scotland* offered a novel and altogether captivating theory to account for its origin [1].[1] According to Geikie, as all well know, the precipitous ridge of pitchstone, which culminates at its eastern extremity in the Sgùrr, is the inverse of an ancient valley sunk by a winding river in the basaltic plateau of the west. Before the development of this river channel, so the theory runs, the sources which had supplied the basalt lava of the plateau had already become extinct; but volcanic activity was not yet entirely banished from the region, and presently a great outpouring of acid lava, entering the valley, flowed for miles along its course, gradually choking it, perhaps even to the brim. The resulting pitchstone has stood the test of time much more securely than the neighbouring basalts, for while these latter have wasted to a level in general lower than that of the old valley floor, the pitchstone itself still remains in large measure unaffected, and thus furnishes a somewhat battered cast of the erstwhile hollow.

The artistic appeal of Sir Archibald Geikie's conception has been admitted on every hand; but, very properly, its credentials have been subjected to a dispassionate and searching scrutiny. In 1906 Dr. Harker, after mapping the district for the Geological Survey, published an alternative interpretation of the pitchstone ridge [3]. We are now asked to abandon the cherished notion of a lava moulded upon the uneven contours of a river valley, and to accept instead that of an intrusive sill irregular and transgressive in its own right.

[1] Footnote numbers in square brackets refer to Bibliography, p. 305.



R. L. Sherlock, Del. ad nat. *Bemrose & Sons Ltd., Collo.*

Foraminifera, Speeton Clay, Yorkshire.

The rumour that the familiar theory had been set aside by so competent an authority created a feeling akin to consternation. Accordingly in 1905, before the publication of the paper just referred to, Dr. Peach joined Dr. Harker in a re-examination of the crucial sections.

Dr. Peach started with a predisposition in favour of Geikie's position, but returned fully convinced by Harker's demonstration of the alternative hypothesis. However, quite undeterred by this notable conversion, Sir Archibald Geikie maintained a position of uncompromising hostility when Harker delivered his paper before the Geological Society of London [3, Discussion, p. 67].

Under these circumstances several of us have experienced a not unnatural desire for personal contact with the evidence. In my own case this desire has now been gratified, for I spent a large part of three days last September reviewing the phenomena upon which Geikie and Harker have concentrated our attention.

There is no excuse at the present stage for a further detailed account of the Sgùrr. What I propose is merely a discussion of Dr. Harker's paper. I am certain that readers will share my gratitude to Dr. Harker himself for allowing me, with the sanction of the Council of the Geological Society, to reproduce Figs. 1, 2, and 3, which have already appeared in the pages of the Quarterly Journal. To Mr. A. Stenhouse we are equally indebted for a hitherto unpublished photograph (Pl. XXII, Fig. 1), which I consider an ocular demonstration of one of Harker's main criticisms of Geikie's description. To Mr. Rhodes, jun., we owe the microphotograph (Pl. XXII, Fig. 2) taken from a specimen collected by myself and now deposited with the Geological Survey; this microphotograph will probably induce many to join with the present writer in accepting Geikie's interpretation as essentially correct, in spite of the error alluded to above.

Internal Intrusion Phenomena.

Sir Archibald Geikie in his early descriptions, and also in his reply to Dr. Harker's criticisms, has laid great stress upon the quite definite stratification of parts of the pitchstone ridge. The interpretation he offers is that the acid lava filled up the old valley in recurrent superimposed sheets of pitchstone and porphyry. In this particular Dr. Harker has furnished an important correction which I am prepared to endorse without reservation. He points out that the supposed porphyry lavas (Harker uses the term felsite) are in reality intrusions cutting the pitchstone mass after the latter, in consolidating, had assumed its columnar jointing (Text-fig. 2). A particularly convincing example of this relation is illustrated in Mr. Stenhouse's photograph (Pl. XXII, Fig. 1). The porphyry or felsite of these intrusive sills is of essentially the same material as the pitchstone itself; the difference is that the former has a more stony, the latter a more glassy, base. Dr. Harker emphasizes the close connexion of the two rock-types by an important observation which, in the limited time at my disposal, I left unchecked. He finds that certain of the definitely intrusive felsite sheets, when followed along their outcrop, merge by insensible gradations into the

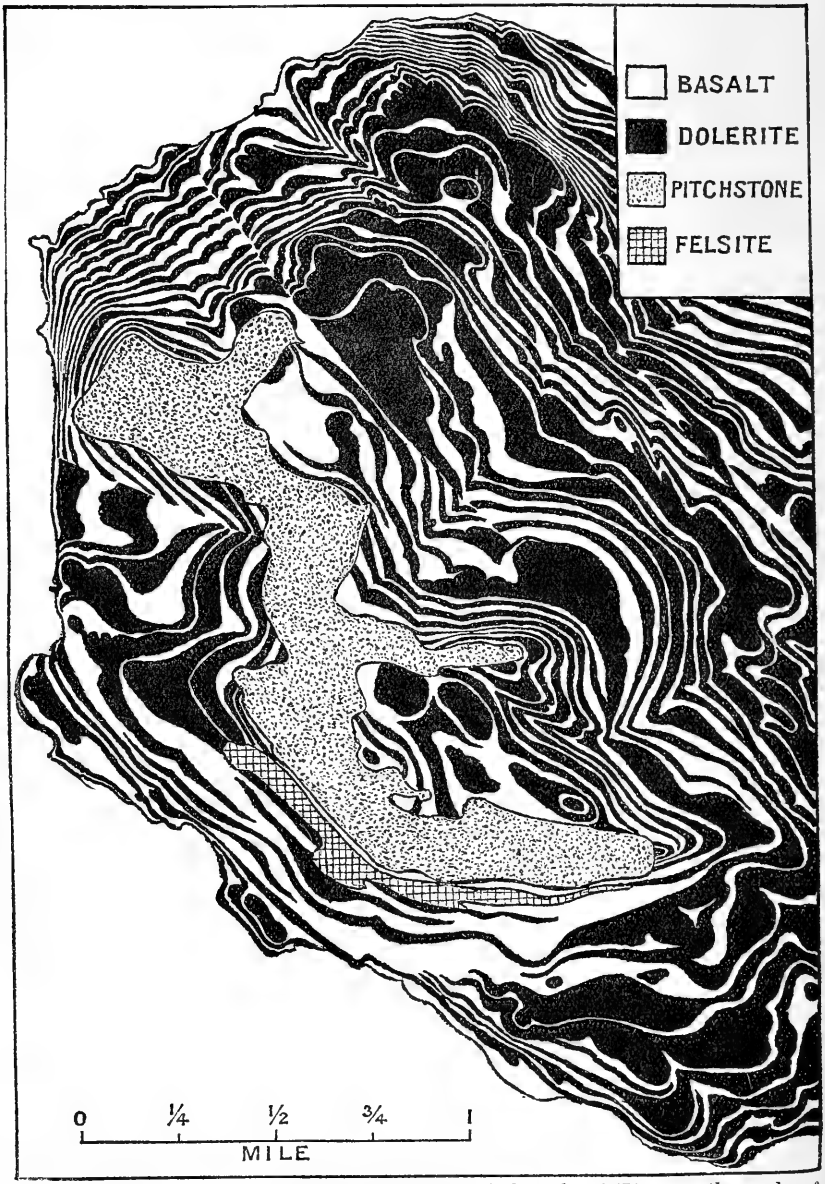


Fig. 1. Sketch-map of the south-western part of the Isle of Eigg, on the scale of 2 inches to the mile. After Harker [3, p. 44].

The felsite shown in this map is quite distinct from the felsite sheets shown in Fig. 2 and described in the text. It forms low ground along with the basalt lavas. The dolerite sheets, indicated by black, are regarded by Harker as sills, by the writer as mainly the interior portions of lava streams.

general body of the pitchstone. I think it may be taken as established that the felsite has followed closely upon the heels of the pitchstone (so far as a distinction can be maintained) and has been supplied from the same source.

There will probably be not a few who will regard this evidence of internal intrusion phenomena as the key to the whole problem, and will agree with Harker in considering the pitchstone-felsite mass a composite sill. I confess that before I visited the exposures I ranked the nature of the stratification of the mass as a crucial point of difference between the two disputants. Now I think otherwise, and remember the late Dr. Tempest Anderson's description of a great eruption of basalt at Matavanu in Savaii, one of the Samoan Islands. The account was given in 1910, when the eruption had been in progress since August, 1905, and the following brief extract will serve as an indication of its bearing upon the matter in hand.

"In the early part of the eruption the lava did not extend far from the crater, the longest streams not exceeding two or three miles, and these did not present the same appearance as subsequently, but were covered with moving scoriæ and stones, so that the whole mountain appeared to be in motion. Later on the lava was often very abundant and very liquid: at times it flowed like a river of water 200 yards wide; at others, as numerous small streams not above 10 feet wide, and in these cases was often so fluid that it nearly all ran away and only left a fresh crust less than two inches thick, over which it was safe to walk next day.

"The large fresh lava-fields soon got crusted over on the surface with solidified lava, and the liquid lava continued to flow underneath. Even at the crater it seldom flowed over the lip, but generally entered holes and tunnels in the sides and flowed underground. The lava-field thus became honeycombed with channels of liquid or pasty lava, which occasionally came to the surface and flooded it with fresh sheets of lava; at other times the surface frequently floated up and was raised by the intrusion of fresh lava underneath, so that what had previously been the course of the valley now became the highest part of the field. Mr. Williams thinks that the lava must be in some places 400 feet thick." [5, pp. 624–5.]

The main lava tunnel at the time of Dr. Tempest Anderson's visit extended as a sinuous line some 10 miles long from the crater to the sea, where it discharged its contents into the sea. Its course was marked at intervals by clouds of vapour escaping from fumaroles. Other fumaroles more to the west indicated the position of a minor subterranean channel.

Let us now turn to a consideration of certain fragmental rocks found in association with the pitchstone, for their importance is, in my opinion, vital.

Fragmental Rocks.

1. A breccia occurs at the base of the pitchstone along the southern face of the ridge for a distance of 500 yards from the eastern termination, and its weathering has given rise to a recess at the foot of the escarpment (YZ, Text-fig. 2). Regarding this breccia Harker writes—

"It shows more or less abundant blocks of the black pitchstone in a soft pale-grey matrix, which is evidently formed by the decay of the pitchstone itself or of its felsitic modification. . . . In addition to the blocks of pitchstone (and felsite), the decomposed matrix encloses in places a few pieces of a blacker and more completely vitreous rock, without conspicuous felspar-crystals, which may be taken to represent a more perfectly glassy selvage to the pitchstone sheet. There are also fragments of extraneous origin, which are sometimes rather abundant at the base of the pale band, but become rare towards its top. Excepting at one locality, to be described below, these extraneous fragments are exclusively of basalt and dolerite, evidently picked up from the subjacent rocks. The inclusion of these is not necessarily connected with the brecciation, for they are found also in the base of the pitchstone where it is unbroken and unaltered: for example, in the spur on the north-eastern side of the ridge near Loch na Mnà Moìre." (Op. cit., p. 47.)

The exceptional locality reserved in the above account for individual treatment is indicated by Z in Fig. 2. Here the extraneous fragments in the basal pitchstone-breccia include not only basalt and dolerite but also Torridon Sandstone and pieces of silicified wood, one of the latter near the bottom of the layer measuring as much as 8 feet in length. The wood is not nearly so conspicuous, however, as might be imagined from Hugh Miller's allusion to a "prostrate forest".

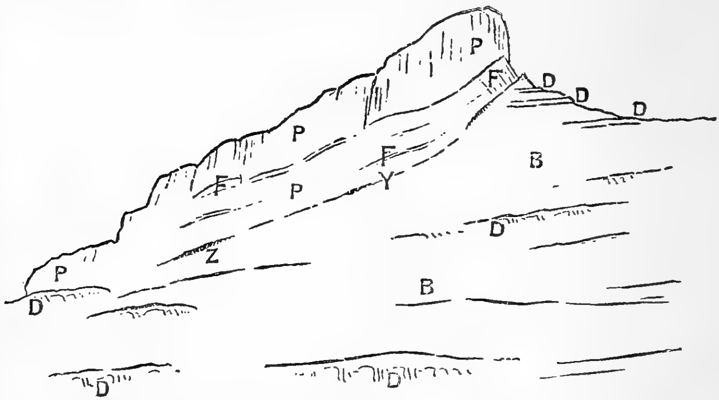


FIG. 2. The Sgùrr of Eigg, seen from the east-south-east, from near Galmisdale. After Harker [3, p. 46].

The lower slopes are of basalt, B, and dolerite, D. The base of the pitchstone, P, weathers into a recess along Y, Z. The pitchstone is intersected by bands of devitrified pitchstone, which may be described as porphyry or felsite, F.

It is easy to account for the presence of such additional foreign fragments at this particular point, for the pitchstone-breccia rests here not directly upon the basalt lavas, but upon a definite breccia deposit made up of basalt lavas and Torridon Sandstone, with fairly abundant pieces of Jurassic sandstone and fossil wood.[1] Beneath is stratified sandstone with a layer of lignite, and beneath this basalt lavas.

For Geikie the breccia deposit and sandstone are the alluvium of the vanished river. For Harker they are an intercalation in the basaltic series. The exposure of the deposit is incomplete, and though

[1] It is by no means certain, however, that the wood in the pitchstone-breccia was not derived directly from growing trees.

it extends for some fifty yards it does not seem possible to the writer to form a definite opinion regarding its relations. What is more immediately attainable is the determination of the precise nature of the pitchstone-breccia. A very thin and irregular representative of this breccia occurs along the steeply inclined base of the pitchstone-felsite complex where the latter terminates in the Sgùrr. A specimen was taken at a point somewhat above the topmost sheet lettered D in Fig. 2. It had the appearance in the hand of being a completely fragmental rock, and as it was fresh—unlike the breccia farther west, which has been weathered to give the recess YZ (Fig. 2)—it was sliced and examined microscopically. The fragmental nature is clearly shown in the slice (Pl. XXII, Fig. 2). The fragments are pitchstone in widely different stages of crystallization, detached and broken porphyritic felspars derived from the pitchstone, and basalt—one small piece of basalt, unlike the others in character, is enclosed in a pellet of glassy pitchstone.[1] A cement of calcite fills the interstices of the breccia.

Some of the weathered breccia of the recess farther west seems to have a definite pitchstone matrix, but some again seems to the eye to be completely fragmental like the specimen just described. At any rate, the occurrence of a genuine fragmental breccia (as opposed to a mere xenolithic rock) at the base of the pitchstone has now been demonstrated, however local the occurrence may be. My own experience leads me to take this as a proof that the pitchstone is a lava. It is a common thing to find definite breccia at the base of lava-flows. In some cases the breccia has resulted from a preliminary shower of ash; in others it is the debris which has slid down the advancing front of the lava. But is it possible to point to any example of an undoubted sill with an open breccia constituting its base?

2. At its north-western end the pitchstone ridge terminates abruptly in a sea-cliff, and there is exposed beneath the pitchstone about a hundred feet of fragmental material (Fig. 3).

With a rope and a trusty companion one could examine at ease the glorious natural section afforded. Like my predecessors, however, I came all unarmed, and had to content myself with hammering over a small part of the fragmental deposit at the south side on the cliff-top. The actual hammering is of course supplemented by the very fine view obtained—especially from the base of the cliff, which can be reached at low-tide after first descending to the shore by a stream-valley some little way farther north.

[1] Anyone wishing to see this xenolithic fragment, which is not shown in the photograph, will find it in a corner of the Survey slice 17181. Dr. Harker, who has kindly examined two additional slices, cut on his suggestion, has drawn my attention to a similar xenolithic fragment on the margin of 17181*c*. In the two cases the enclosed basalt is of one and the same type, and is markedly distinct from the other pieces of basalt scattered throughout the slices. Dr. Harker (p. 306) states his opinion that in a few cases glass is adherent to these latter also. It is sometimes difficult in a slide of a breccia to distinguish with certainty between mere contact and actual continuity, and I am unable to agree with Dr. Harker in this particular, but fortunately the difference in interpretation does not appear essential to the argument.

Geikie has taken the more obvious course of regarding this fragmental deposit as a river-gravel underlying a pitchstone lava. Harker, assured from the other evidence that the pitchstone is intrusive, holds that the fragmental deposit is an agglomerate enclosed in a funnel-shaped neck which does not pierce the lower lavas of the cliff-face *because it passes behind them.* For Harker the association of the pitchstone and this fragmental deposit is nothing more than a coincidence. So far as the material of the deposit goes, I know of nothing to decide between the two interpretations. The deposit consists in large measure of subangular blocks of vesicular basalt, with a fair proportion of well-rounded boulders derived from the sounder portions of the basaltic flows; small pieces of Torridon Sandstone also occur, but are comparatively rare; fragments of pitchstone are altogether absent.

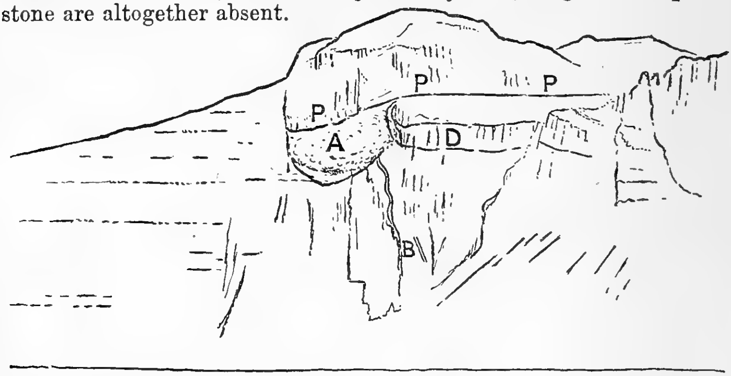


Fig. 3.—Bidein Boidheach, showing the sea-cliff in which the ridge of the Sgùrr terminates north-westward. After Harker [3, p. 53].

The cliff is made of alternations of basalt, B, and dolerite, D, terminating against pitchstone, P, and also against a fragmental rock, A, which Harker regards as agglomerate in a neck, and Geikie as gravel in a river-channel. A particularly massive band of dolerite along the cliff-top, south of the pitchstone and fragmental rock, is lettered D. A basalt dyke, B, cuts the basalt-dolerite succession of the cliff, but not the fragmental rock, A.

A point very greatly in favour of Geikie's reading is the fact that, as seen in the cliff, the pitchstone exactly fits into the upper part of the hollow, in the bottom of which, apparently at any rate, the fragmental material lies (Fig. 3, A). If we accept Harker's hypothesis it is surely remarkable that such a delicate adjustment should occur at any place at all, and doubly strange that the modern cliff should be cut to the precise position requisite to reveal it.

I am very reluctant indeed under such circumstances to relinquish Geikie's interpretation, which accounts so simply for one sweeping curve furnishing the boundary of pitchstone and fragmental deposit alike.

Dr. Harker has gone further than mere suggestion of a possible accidental companionship between the pitchstone and the fragmental material. He believes that he can actually prove that the two belong to widely separate epochs. It is necessary to examine very thoroughly the foundations upon which he builds, although to do so involves a considerable digression.

The plateau lavas of Eigg show the usual step, or trap, features. Harder bands give rise to escarpments, softer bands to recesses or flat terraces. The harder bands are generally more coarsely crystalline than the softer and are often ophitic, while their exposures show vertical joints which give rise occasionally to perfect columnar structure; such harder bands are Harker's dolerites. The softer bands are finer in crystallization, and typically granulitic and amygdaloidal; these are Harker's basalts (Fig. 1).

Harker's contention is that the dolerites, as a class, are intrusive into the basalts. Naturally, when several years ago Mr. Maufe, Mr. Wright, and I began work for the Geological Survey in the Tertiary igneous district of Mull, we considered this important suggestion very carefully indeed; but neither in Mull, nor Morvern, nor yet in Skye, were we able to adopt it. I make this statement because I wish to disclaim at once any originality for my position in this matter, since I merely hold it in common with most of those, old and young, with whom I have had the privilege of discussion in the field. I also wish to excuse myself for not handling the subject from the general standpoint of Hebridean geology, although my friend Dr. Harker will doubtless feel that a limited treatment is inadequate.

Restricting attention to Eigg, I give the following reason for regarding the great majority of the dolerite sheets of the island as merely the solid cores of lava-flows. In very many representative cases I have definitely followed dolerite merging upward into slag. The vesicular structure starts before the solidarity and the vertical jointing of the dolerite disappears. The transition is perfect. The proof to my mind is rendered complete by finding, in not a few such instances, that the slaggy top has weathered, in large measure, to a red soil before being covered by the next succeeding lava. One may examine successive illustrations of this phenomenon clearly exposed in the precipitous face of Dunan Thalasgair at the northern end of the island. After having seen this convincing section it was pleasant to read in Geikie's description [2, p. 293]—

"Here and there, indeed, between the beds, we not unfrequently meet with a thin irregular seam of red earth, which, when fine, might be called bole. In the cliff below Dunan Thalasgair, for example, several of the dolerite beds are not only covered by this substance, but seem to pass into it." Careful scrutiny left no doubt in my mind of the reality of this passage from dolerite to red earth. The bottoms of the dolerite sheets are in like manner generally vesicular and fairly often brecciated, though to a much less extent than their upper portions.

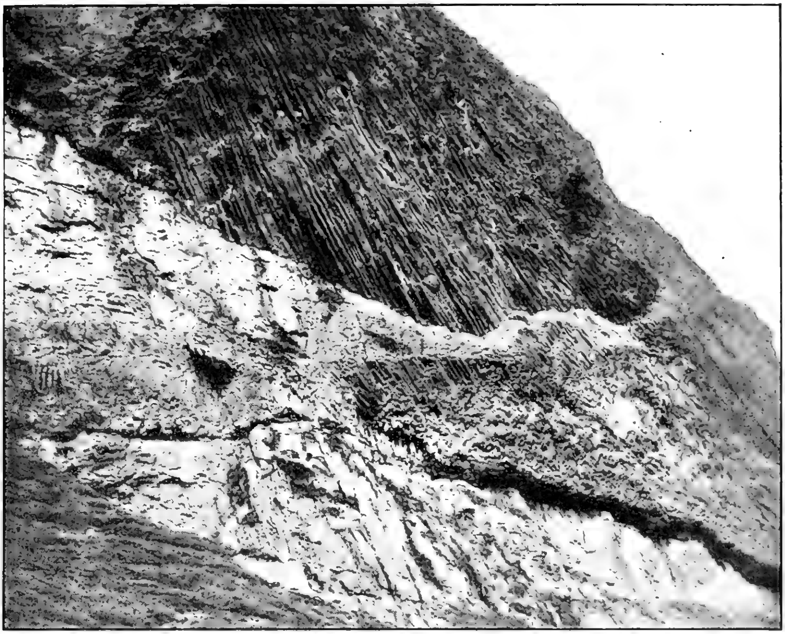
Now Harker writes [3, p. 41]: "It is to be remarked that sheets of dolerite, in all respects identical with those in question, occur, not only among the basalts, but also among the subjacent Jurassic strata along the eastern coast of Skye and in the northern part of Eigg. Here their intrusive nature has long been recognized. It seems an arbitrary interpretation to make the dolerites intrusive when they occur below the base of the basalt group, and extrusive when they occur above that line." The crux of this argument lies in the premise that the dolerite sheets in the two cases are "in all respects identical". I visited the particular zone of Jurassic rocks, which in Eigg is crowded with basalt and dolerite sills, and found that these sills differed from the dolerite sheets which have been described above in being clearly transgressive and in having *compact chilled upper and lower surfaces.* Similar intrusions occur here and there among the lavas and are quite conspicuous in good exposures; one such may be readily visited south of the pier on the east coast. In all this discussion I find myself in essential agreement with Sir Archibald Geikie's early descriptions of the island [2].

Now let us return once more to the sea-cliff (Fig. 3). Looking at the fragmental deposit it is clear that it includes harder and softer elements, the former often conspicuous as rounded boulders, the latter crumbling away to earth. I feel quite confident myself that these harder and softer elements correspond to the doleritic and basaltic material respectively of the lava succession alongside. In agreement with this I found in the accessible part of the deposit dolerite fragments, one big block in particular associated with crumbling amygdaloidal lumps of basalt. But Harker did not notice any dolerite at all [3, p. 54], and accounted for its supposed absence on the view that the deposit occupies a neck which was blown through the basalt lavas before these latter had been invaded by dolerite sills. In fact, the doleritic bands in the lava sequence and also the dyke marked B in Fig. 3 are regarded by Harker as intrusions of later date than the fragmental deposit against which they terminate so abruptly.

The view just outlined was largely based upon an examination of the accessible southern edge of the exposure, where it was thought that clear evidence existed of a dolerite sill being deflected upwards along the steep margin of the deposit. Dr. Harker ascribes this observation to Dr. Peach. I can only say that I consider the appearances relied upon entirely deceptive. Fig. 3 shows the dolerite in question, a particularly strong band marked D. It caps the cliff for some distance south of the fragmental deposit. If it recurs to the north of the latter it must have become considerably thinner in the interval so as to be no longer distinguishable from its fellows. Now, suppose one walks from the south along the edge of the cliff towards the fragmental deposit, one finds that the surface of the dolerite as exposed rises somewhat suddenly just before the deposit is reached. This has given rise to the misconception that the dolerite is deflected upward as a tongue along the junction. But the upper surface of the exposure is in this case merely an accident of erosion: there is no change of texture, no line of vesicles, nor any structure at all that I could find, to suggest that the upper surface as seen corresponds closely with the original upper surface of the dolerite sheet. But of more importance than this negative observation are the actual appearances presented at the junction of the dolerite and the fragmental deposit, appearances which seem to have been hitherto quite overlooked. The pebbly material is packed into little hollows in the steeply truncated face of the dolerite. The deposit has not been indurated. The dolerite, even at the contact, maintains its doleritic texture without the least sign of chilling. I left the exposure convinced that this dolerite sheet (whether it be lava or sill I am uncertain) is of earlier date than the fragmental rock, and that the latter has been heaped against it.

Now the bearing of all this upon the point at issue is that Harker claims to have demonstrated that the fragmental deposit is earlier than a suite of dolerite sills, in their turn earlier than the pitchstone; that, in fact, a great epoch of sill-intrusion separated the period of formation of the deposit from the period of the advent of the pitchstone; and accordingly that the conjunction of the fragmental deposit and the pitchstone must be fortuitous. If my criticism is justified, this line of argument can no longer be maintained.

We shall now briefly consider another objection of a very different type.



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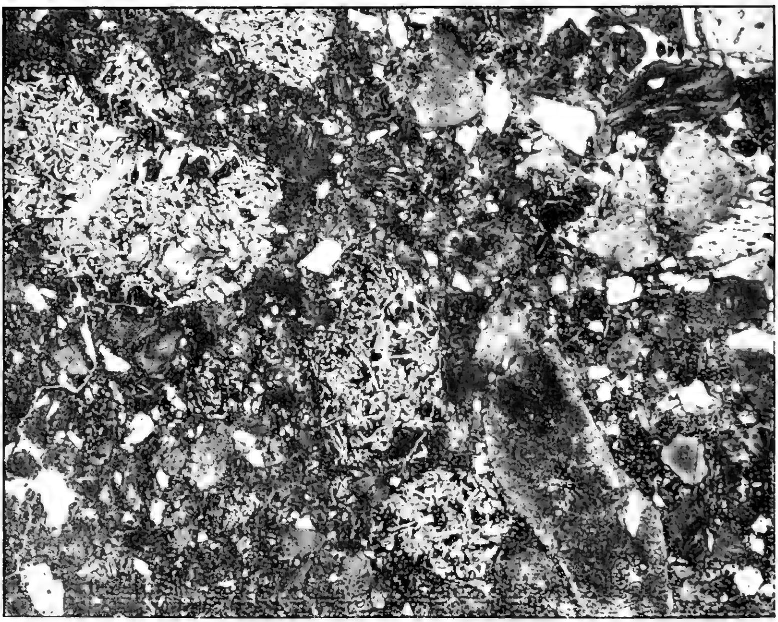


2

Sgùrr of Eigg.

The Form of the Pitchstone.

Dr. Harker writes [3, p. 48]—

"The elongated and curving trend of the ridge, with its projecting arms, seems at first to accord with the supposition that the pitchstone occupies an old valley with smaller tributary glens; and it is also very noticeable that, at the base of the escarpment, the lower surface of the pitchstone has in most places an inward slope."

He then proceeds to point out difficulties in the way of accepting this hypothesis, which, of course, is the one proposed by Geikie. I have not examined all the evidence Harker cites in this connexion, but I did visit the locality to which apparently he attaches most weight. Here a spur of pitchstone running N.N.E. and S.S.W. joins the main ridge near its western termination. Harker's contention is that if this spur is the cast of a tributary valley, then the latter can be shown to have drained uphill at some parts of its course. All that is clear, it seems to me, is that the edge of the pitchstone in this spur does undulate quite sharply in places, just as a road running parallel with a stream constantly rises and falls. For my own part, I am unable to assert the existence of a regular thalweg buried beneath the pitchstone here, but I find no difficulty in imagining that such exists. At the end of the spur the base of the pitchstone, as seen in cross-section, is considerably higher than at the termination of the main ridge in the neighbouring sea-cliff.

Conclusion.

A careful re-examination of the evidence has led me to accept Geikie's interpretation of the Sgùrr of Eigg pitchstone as a lava-stream moulded upon an ancient river-valley.

With Harker, however, I believe that the apparent stratification of the mass is due to injection, and not, as Geikie thought, to the piling of lava-flow upon lava-flow. Certain other criticisms advanced by Harker I have been unable to adopt.

BIBLIOGRAPHY.

1. A. Geikie, *Scenery of Scotland*, 1st ed., 1865, pp. 278–82. For details see [2].

2. A. Geikie, "On the Tertiary Volcanic Rocks of the British Islands": Quart. Journ. Geol. Soc., vol. xxvii, p. 279, 1871.

3. A. Harker, "The Geological Structure of the Sgùrr of Eigg": Quart. Journ. Geol. Soc., vol. lxii, p. 40, 1906.

4. A. Harker, in Sheet 60 of the Geol. Survey 1 in. Map of Scotland, and in the accompanying memoir, *The Geology of the Small Isles of Inverness-shire*, 1908. For details see [3].

5. Tempest Anderson, "The Volcano of Matavanu in Savii": Quart. Journ. Geol. Soc., vol. lxvi, p. 621, 1910.

EXPLANATION OF PLATE XXII.

Fig. 1. Pale felsite or porphyry injections (F of Text-fig. 2, p. 300) cutting darker pitchstone of Sgùrr of Eigg ridge. Photo by A. Stenhouse.

Fig. 2. Basal breccia of Sgùrr of Eigg pitchstone (a little above the top layer lettered D in Text-fig. 2, p. 300). × 14·5 diam. Slice No. 17181. The fragments with network structure are basalt, the rest pitchstone and felspar derived from same. Microphoto by J. Rhodes, jun.

III.—The Sgùrr of Eigg: some Comments on Mr. Bailey's Paper.

By Alfred Harker, M.A., F.R.S.

Mr. BAILEY has very kindly permitted me to see his manuscript, and also to examine a specimen and slice of the rock which he regards as a volcanic breccia underlying the pitchstone. Since he attaches some importance to this rock, I will consider it first.

The natural base of the thick pitchstone sheet is made by a band of more glassy aspect, almost like an obsidian. The microscope shows that this, apart from the usual enclosed crystals, is a light-brown glass, free from the crowds of crystallites found in the ordinary pitchstone. Another feature is that it encloses numerous little fragments of basalt. These indeed, with occasional larger pieces, pass up for some feet into the pitchstone, but they are most abundant near the lower surface. Such inclusions, picked up from the contiguous rocks, may occur both in lava-flows and intrusive sills, but, so far as my experience goes, are more frequent in the latter. The obsidian-like band is well seen, fresh and intact, at places on the northern side of the Sgùrr; but elsewhere it is much brecciated, and usually much decomposed in addition. The brecciation is of such a kind that pieces of the normal pitchstone have become mingled with the debris of the more glassy variety. Mr. Bailey has quoted part of my description of this brecciated basal band as it is exposed, in a decomposed state, on the southern side of the ridge. That it is a part of the pitchstone sheet, not a separate underlying deposit, is there clearly demonstrated: see fig. 6 on p. 60 of my paper. Mr. Bailey's specimen comes, I do not doubt, from a part of the same band which is brecciated but not decomposed. The small fragments of basalt in it represent, in my view, the inclusions which always occur in the basal pitchstone or obsidian. In the course of brecciation they have usually become detached from their more brittle matrix; but one or two, as seen in the slice, seem to me to have relics of brown glass still adherent to them, and one is completely enclosed in a shell of glass, a fact which my friend is content to record without comment. For me, therefore, his rock is no volcanic breccia, but merely the brecciated base of the pitchstone sheet. Such brecciation again affords no criterion as between a lava-flow and a sill.

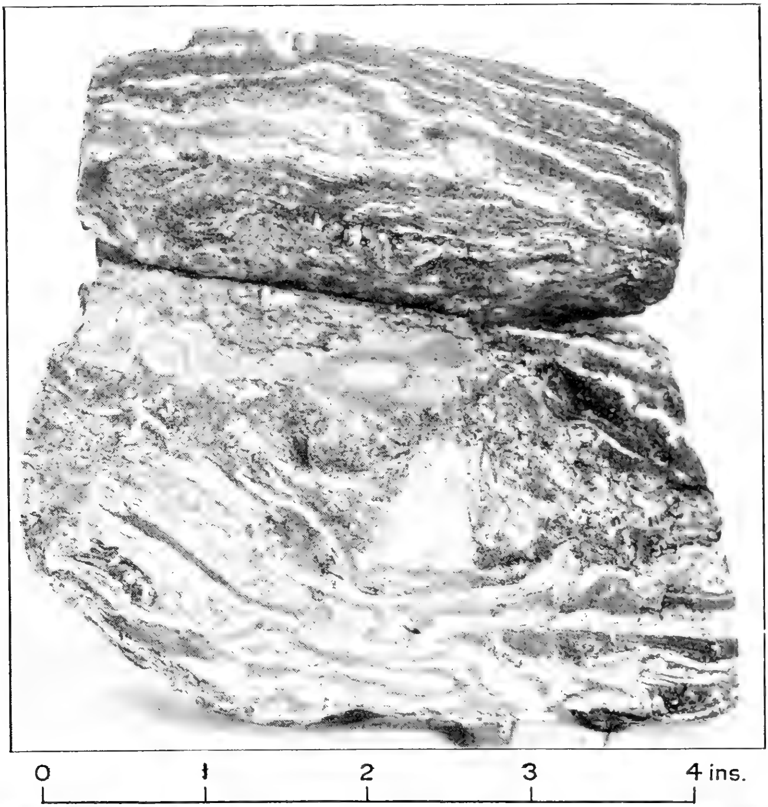
Mr. Bailey next carries us to the west coast, and discusses the fragmental accumulation there exposed in the cliff. This Sir Archibald Geikie regarded as a thick deposit of river-gravel, thrown down (a circumstance requiring some explanation) just where the valley narrowed to a gorge. To me its characters are not like those of a river-gravel, and it is certainly very different from the accumulation seen on the south side of the Sgùrr, with which it was correlated. My own interpretation has been set forth elsewhere. Concerning the thick dolerite sheet seen just south of this spot, I have no new observation to record. I have not visited the locality since Dr. Peach and I saw, or thought that we saw, the dolerite turning abruptly upward on encountering the agglomerate mass. The form of the pitchstone surface here, with its steep northern boundary, I ascribe to the intrusion ploughing into the agglomerate and occupying part of its funnel. It is for Mr. Bailey, who distrusts coincidences, to explain why, on his alternative reading of the relations, the thick dolerite sheet should select this critical spot for dying out abruptly.

My generalization concerning the intrusive nature of most of the strong dolerite sheets in the region was not based especially upon the mapping of Eigg, though I find it borne out in that island. When I wrote the passage quoted by Mr. Bailey, I had in mind more particularly the fine cliff-sections on the eastern coast of Skye, rendered classic by Macculloch. The close resemblance in behaviour there between the strong dolerite sheets in the basalt series and those in the Jurassic strata below seems to me most striking. It must surely have been noticed by Sir Archibald Geikie when he set down both as lavas. He has changed his opinion as regards the lower sheets, but apparently retains it as regards the higher ones. If any reader is interested in this question, so fundamental in British Tertiary geology, let him turn to Sir Archibald's paper of 1896 (Q.J.G.S., vol. lii, pp. 331–405) and examine the numerous sections by which it is illustrated. My contention is broadly (though I have no personal knowledge of the Faroe Isles) that the sheets there marked by vertical lines are in general intrusive sills. Further, I maintain that this is in some cases proclaimed by the drawings themselves: in figs. 7, 12, 13, 17, for instance, the transgressive behaviour is faithfully rendered. Similar sections may be seen in Eigg; I remember pointing out to Dr. Peach, on the slopes of the Sgùrr, a dolerite sheet cutting obliquely across well-marked flow-lines in a basalt.

It would appear from Mr. Bailey's remarks that he regards chilled edges as one of the criteria of an intrusive sill. For some of my friends on the Geological Survey this matter of chilled edges seems to have become, in these latter years, a kind of cheap and infallible touchstone. Chilled edges, an intrusion; no chilled edges, a lava-flow: it is at least a rule easily remembered. Now, plainly, an igneous rock will have chilled edges if its magma has been rapidly cooled at its boundary. Rapid cooling of the surface is assured in the case of an ordinary lava-flow (I say nothing of freaks like Matavanu), while for a sill or dyke the question is one of conditions. Nor is it difficult to see what some of the conditions are. There is in the first place the temperature of the country-rocks. The principal sill epoch came immediately after a prolonged succession of plutonic intrusions, when the rocks of the whole region, and especially of the neighbourhood of the plutonic centres, had been raised to a considerably high temperature. Cooling must have been a very gradual process; and it is a matter of observation that, in the long succession of minor intrusions (basic dykes and sheets) which followed, sharpness of boundary and all the indications of rapid chilling become marked, and increasingly marked, as we pass from earlier to later groups of intrusions. Tachylytic selvages, for instance, are scarcely seen except on sheets and dykes which cut all other rocks; and even there any noteworthy development of tachylyte is found only in places remote from the plutonic centres. In the dolerite sills themselves there is an unmistakable relation between the degree of chilling and the distance from the special centres. Indeed, the thing is a feature of the landscape; for any tourist in the Inner Hebrides must observe how the columnar jointing becomes more strongly pronounced as we recede from the gabbro and granite hills.

Another important factor is the varying thermal conductivity of the country-rocks. A basalt dyke, which exhibits strongly chilled edges where it intersects a sound crystalline dolerite, may show only a very slight modification against a decaying amygdaloidal basalt, and absolutely no sign of chilling where it cuts one of the bands of clay or bole. Professor Kendall long ago drew attention to these differences dependent on specific thermal conductivity, and every student of Hebridean geology must have had many opportunities of observing such phenomena. Again, it is true, as Mr. Bailey remarks, that the disputed dolerite sheets are often intimately associated with the bands of red earth or bole; and this is not surprising, for a sill-intrusion naturally follows the plane of least resistance. But when a sill rests on such a blanket, and is covered by another blanket, viz. the scoriaceous base of the overlying flow, it is too much to demand that it shall show evidence of rapid chilling. The appearance of blending of the dolerite with the bole may be seen equally at the edge of a dyke. I am not attempting to set forth all the elements of the problem, but rather to point out that it is not so simple as is sometimes assumed. In such a case, I submit, we are more likely to reach the truth by trying to understand the conditions than by applying a universal formula of the 'rule of thumb' order.

Finally, Mr. Bailey considers the inclination of the lower surface of the pitchstone sheet at certain localities. Since we unfortunately possess no large-scale contoured map of Eigg, this question can scarcely be discussed with profit except on the spot. But Mr. Bailey passes over without notice a point which seems to me the most decisive of all. The sides of every driftless valley in the basaltic region are *conspicuously terraced*, the strong sheets of dolerite standing out beyond the crumbling amygdaloidal basalts. Sir Archibald Geikie's hypothetical valley has nothing of this character. The base of the pitchstone is an irregularly curved surface, for acid intrusions seldom attain to the perfectly conformable habit seen in many basic sills; but the surface is everywhere a *clean-cut* one, passing across harder and softer sheets indifferently. Let any geologist look at the eastward termination of the Sgùrr, or at any good photograph of it, or even at the small outline sketch reproduced in Mr. Bailey's paper: let him compare the pitchstone base with the terraced slope of the hillside below, and pronounce whether the former represents an erosion-surface or, as I maintain, an intrusive junction.



1

2

Fig. 1. altered clay from near the granite; Fig. 2. clay about 8 feet from the granite. On land worked by Tekka Co., Ltd.

IV.—The Junction of the Malayan Gondwana Clays with the Mesozoic Granite of the Malay Peninsula.

By J. B. Scrivenor, M.A., F.G.S.

(PLATES XXIII, XXIV.)

ONE of the drawbacks of working in a distant land is that the valuable help of the friendly critic is rarely available, and that, therefore, however strongly the truth of conclusions arrived at may be felt by oneself, it is impossible to expect readers in England to accept without reserve statements that may with perfect justice be said to require corroboration by other observers. I have felt the force of this consideration particularly in the case of the clays of the Malayan Gondwana rocks, which I have described in more than one publication;[1] and as the conclusions in those descriptions are so far removed from what was to be expected in a country where recent alluvium was until quite lately believed to be the most important formation, it is, I think, advisable to place on record in some detail any corroborative evidence that may be brought to light. An additional reason for this course is the constant change in the mine-sections owing to mining operations, and also to the rapidity with which sections weather.

The conclusions put forward in the publications referred to, stated briefly, are that masses of clay in the Kinta district, formerly believed to be recent alluvium, are, as a matter of fact, part of the Malayan Gondwana rocks, that they are older than the Mesozoic granite which forms the Main Range of the Peninsula and other ranges, and that they are of glacial origin. I need not repeat here the evidence already given, and the object of this paper is to present further evidence on one point only, namely the relative age of the clays and the granite. As far as the economics of the country are concerned, the question of the glacial origin of the clays is a matter of no very great importance, nor is it a theory that has been "nailed to the mast" by its author. It best explains the facts seen in the field, but is nevertheless open to objections, and if anyone will produce a more acceptable theory I am ready to give it preference.[2] The proposition that the clays are older than the granite, however, is a matter of great importance from both the scientific and economic standpoint. If it can be proved that these clays are younger than the Mesozoic granite, then the whole argument of a Gondwana cold climate leaving its mark and of a Gondwana tin-field being preserved in the Kinta district would be shattered at a blow. I am confident that it cannot be so destroyed, but it would be wrong to expect others who have not seen the field-sections to share my confidence. I propose, therefore, to describe with the help of some photographs two new sections of the junction between the clays and the granite, which, if they do not remove all doubt on the subject, will at any rate show that to prove the clays younger than the granite would be a very difficult matter.

[1] "The Gopeng Beds of Kinta": Q.J.G.S., lxviii, pp. 140–63, 1912. "Geological History of the Malay Peninsula": Q.J.G.S., lxviii, p. 350, etc., 1912. *The Geology and Mining Industry of the Kinta District*, Kuala Lumpur, 1913, pp. 27–43.

[2] The late Dr. Tempest Anderson saw some of the clays with boulders in 1913, and remarked on their similarity to glacial deposits.

The two sections occur on the east side of the Kinta Valley, one on the land worked by the Tekka Company, Ltd., the other on the land worked by the Société des Étains de Tekka. Both these mines lie to the north of Gopeng (*vide* sketch-map with the *Geology and Mining Industry of the Kinta Valley*).

The Tekka Company Section.

On the Tekka Company's land the Gondwana clay near the granite is of a deep-red colour. Boulders of considerable size are rare in the clay, in fact the only big boulders I have seen in situ on this mine are those of corundum previously described. Lately, however, I have seen some good sections with small boulders bearing a striking resemblance to Boulder-clay. At one part of the mine, newly opened up, the clays can be followed for a distance of about 80 yards right up to a well-exposed junction with the granite, which is here soft owing to its being rich in kaolinite and also to the effect of weathering. Perhaps the kaolinite was partly formed by weathering.

At a distance of about 30 feet from the junction the clay shows no sign of alteration, but within that distance coloured streaks appear, that might in some places be described as foliæ, and increase as the granite is approached, until at the junction the clay, instead of being a uniform deep-red colour, is a roughly foliated and banded mass of red, black, white, and yellow streaks, and is traversed by small, hard veins of blue tourmaline, which are not easily observable until the clay is broken up. Pl. XXIII, Fig. 2, is a photograph of a portion of the clay about 8 feet from the granite. Pl. XXIII, Fig. 1,[1] is a photograph on a larger scale of similar altered clay. The black streaks were found to contain iron and manganese. Mineral matter heavier than 2·8 (specific gravity) separated from the altered clay in bulk was found to be chiefly blue tourmaline, but comprised a few grains believed to be secondary corundum and hercynite.

Near by this section the clay is traversed by white veins which are fairly hard and fine-grained. Some are as much as 6 inches thick, but the majority are smaller than that. Sections and separations show them to consist of white mica and fluorite as a fine mosaic of irregular flakes and grains, with minute grains and acicular particles of corundum that form veinlets in the mosaic, and a small quantity of another mineral believed to be a spinel. The corundum in these veins must not be confounded with the corundum boulders. It was clearly brought into being by the influence of the granite, whereas the big corundum boulders are detrital components of the clay.

The granite junction is irregular and, apart from the evidence of alteration, leaves no doubt in the writer's mind that the granite was intruded into the clay.

The Société des Étains de Tekka Section. (Plate XXIV.)

This section is even better than that just described. In the mine a large intrusive mass of granite with tourmaline veins has been disclosed. On either side, as seen now in section, it falls away at an angle of about 45° and is in part fairly hard. On the north side of the granite a big face of clay has been exposed for some time,

[1] The scale of inches on the Plate refers to the upper figure (Fig. 1).

C

G

Junction of clay (C) and intrusive granite (G) on land worked by the Société des Étains de Tekka, Malay Peninsula.

extending from the granite junction about 100 feet. At about 80 feet from the granite pebbly beds are exposed. One of them passes downwards vertically into clay, the pebbles becoming fewer and fewer. From the pebbly beds, which are grey, to the granite the whole section is of deep-red clay with very little stone. At the junction shown in Plate XXIV, as clean a junction between two rocks as one can hope to see, the streakiness observed in the Tekka Company's section is not so extensively developed, but is visible both in the vertical section and in the floor of the mine, where the junction can also be followed. No tourmaline or fluorite and mica veins were seen, but in a section in another mine hard by a vein of blue tourmaline was traced for 40 feet from the granite into the clay.

On the south side of the granite the clay has been largely worked away, but an interesting point is that here one of the kaolin veins I have described elsewhere as traversing the clays was seen traversing the granite. These veins of almost pure kaolinite, without any proved felspar, are of exceptional interest, but this is not the place to discuss them.

The Present State of the Clay at the Junction.

To anyone unacquainted with the effects of tropical weathering a surprising feature of the clay in both these sections at the granite junction would be that it is soft enough to be cut by hand. Shales, and some rocks harder than shales, generally weather to the consistency of cheese in the Malay States, but in every section I have seen the bedding is preserved up to the subsoil. At a granite junction, however, where the latter is clearly intrusive, one would expect some degree of greater hardness. In the case of shales and other rocks this is found, and the lack of it in these clays is, I think, ascribable to two causes. In the first place the clays, although they contain a certain amount of grit, are everywhere rich in kaolinite, and therefore it may be assumed that when the granite was intruded they were very plastic and yielded easily to the pressure of the earth-movements. This would result in the generation of a relatively small amount of heat compared with less plastic rocks, and consequently less alteration. Secondly, supposing silicification had been set up, resulting in an indurated clay, the evidence of the effect of ground-water on the large outcrops of quartzite in the country shows that in the present position of the clays the siliceous cement would certainly have been removed by now.

V.—The Fossils found on the Site of the Torquay Museum.

By A. J. Jukes-Browne, F.R.S., F.G.S., and R. B. Newton, F.G.S.

Part I. By A. J. Jukes-Browne.

THE fossils which form the subject of this notice were obtained from the slates exposed in the excavations for the foundations of the 'Pengelly' Lecture Hall, which was added to the Museum of the Torquay Natural History Society in 1894. They were collected by Mr. W. J. Else, the late Curator of the Museum, and were examined by the late Rev. G. F. Whidborne, who published some account of them in the Geological Magazine for 1901, p. 533.

When Mr. Whidborne's paper was published I was not specially interested in the details of the geological structure of Torquay, but since then I have paid much attention to these local details and have collected fossils from all existing exposures. I was consequently surprised to find on reference to the note published by Mr. Whidborne that he had regarded these fossils as a Lower Devonian assemblage, in spite of the fact that the Museum is in close contiguity to a tract of Middle Devonian Limestone, as shown on the map of the Geological Survey published in 1898. Moreover, he quoted a statement made by the late Mr. A. Somervail regarding the stratigraphical position of the slates which is entirely incorrect. It is not true that in ascending the Torwood valley from The Strand one passes over a descending series of rocks. The beds underlying The Strand are shaly slates, which dip northward under limestone, and the same slates run up the valley to and a little beyond the Museum; they are then succeeded by limestone which crosses the valley in a south-east direction, and about 100 yards higher up this is faulted against slates which are believed to be of Lower Devonian age. There is therefore every reason to suppose that the slates are the Calceola Shales and pass under the adjacent limestone. Another band of similar shale extends from Torwood Gardens to Meadfoot Beach, where it can be seen to pass under the limestone. It should also be mentioned that in his memoir on the *Geology of the Country around Torquay* (1903) Mr. Ussher referred the slates of the Museum site to the Eifelian (=Calceola Shales) without any mention of Mr. Whidborne's opinion about the fauna.

It would require very strong palæontological evidence to establish the existence of Lower Devonian below the Museum, and, though Mr. Whidborne headed his note "Lower Devonian Fossils from Torquay", it would seem that he was prepared to admit a doubt about the matter, for his opinion is expressed as follows: "It will be seen that they may on the whole be referred to the Upper Coblenzien or to a slightly higher horizon." Now the next stage in the French sequence is the Eifelian, or Couvinian as the Belgians prefer to call it, i.e. the lowest part of the Middle Devonian.

The fauna as described by Mr. Whidborne, omitting Corals and Bryozoa, comprised thirteen identified species, and of these nine range up from the Coblencian to the Middle Devonian, but four of them are essentially Lower Devonian and do not range upward. It thus becomes a question whether these four species were correctly identified. Moreover, I found that though Mr. Whidborne had returned the specimens which he had studied to the Museum, only those which he had actually figured were named and mounted. The rest were put away in drawers and only bore small numbers, which probably referred to some list, but about which nothing was known at the Museum nor by Mr. Else. Consequently some of the specimens which Mr. Whidborne had named but had not figured could not be recognized. There were also specimens in a box, and I am informed by Mr. Else that the material examined by Mr. Whidborne did not include all the fossils obtained.

Under these circumstances it was evident that the whole collection needed revision and also that they should be submitted to someone who was specially acquainted with the Brachiopoda, as the majority of the species belong to that class. Application was accordingly made to the British Museum, with the result that Mr. R. B. Newton kindly undertook to examine a selection of the specimens. The whole collection was then sent to me and the best specimens were selected for transmission to Mr. Newton, but I retained most of the corals for further investigation.

It should here be mentioned that all the fossils are either internal casts or external impressions, the actual shells and calcareous parts having been dissolved and carried away by percolating water.

Mr. Whidborne described five species of Anthozoa, but the specimens on which he based three of these identifications could not be found either in the Torquay Museum or in the Sedgwick Museum at Cambridge, to which Mr. Whidborne's own collection was presented. Two of these five species were described and figured, and three were described but not figured, the latter being *Hallia quadripartita*, Frech, *Amplexus* sp., and *Metriophyllum Elsii* (new species, which should be written *M. Elsei*).

Hallia quadripartita was described from two specimens, one from this locality and a better one from "near Walls Hill". Neither of these specimens can now be found. Frech described this as a new species, but Schlüter afterwards identified it as only a variety of his *Aulacophyllum looghiense*, and I think it safer to adopt his opinion.[1]

The second species was identified as belonging to the genus *Amplexus*, from a single distorted cast of the cup, which was about 25 mm. deep by 25 mm. in width with twenty-eight major septa. This specimen cannot now be found.

Metriophyllum Elsei is stated to be the commonest coral in these slates, and there are some thirteen specimens which resemble one another and may belong to the genus *Metriophyllum*, but they are merely casts and most of them are crushed. The number of major septa seems to be from eighteen to twenty and not uniformly sixteen as stated by Mr. Whidborne; they are twisted as they approach the centre, but it is difficult to say whether they formed a pseudo-columella. Dr. Vaughan, who has seen them, thinks Mr. Whidborne must have had before him a better specimen than any of those now in the Museum, which are not sufficiently good for even generic identification.

Besides the corals above mentioned there are four casts among those in the Museum which clearly belong to a different genus. They have the general aspect of *Petraia* or *Streptelasma* and have a strong resemblance to the small Devonian corals which Schlüter has referred to the genus *Duncanella* of Nicholson.[2] In fact, they may be casts of the two species described by him under the names of *Duncanella major* and *D. pygmæa* on pp. 16, 17 of the work above

[1] "Anthozoen des rhein. Mittel-Devon": Herausg. Kön. Preuss. geol. Landes, 1889, p. 32.
[2] "Anthozoen des rhein. Mittel-Devon": Herausg. Kön. Preuss. geol. Landes, 1889.

cited and figured on pl. ii, figs. 9–15, both being from the Middle Devonian limestones of the Eifel.

The two larger Torquay specimens had from sixteen to eighteen straight septa, which did not reach the centre, and an equal number of rather shorter secondary septa, the total being thus from thirty-two to thirty-six septa. There was no columella. The diameter is about 8 mm. and the length may have been about 12 mm. The two smaller specimens are in one piece of slate and have only twenty-eight septa arranged in the same way at equal distances. Their diameter is only 4 mm., and they seem to agree with Schlüter's description and figures of *Duncanella pygmæa*, except that the latter is said to have only twenty-four septa. Dr. Vaughan has seen these specimens and remarks that they appear to be specialized Streptelasmids and that they may belong to *Duncanella*, but as they are casts he does not think it safe to venture on more precise identification.

The two species of corals figured by Mr. Whidborne were a *Pleurodictyum* and a *Cladochonus*. To the former he gave the name of *pachyporoides*, and there seems little doubt that it is really a *Pleurodictyum*, though it has the habit and branching growth of a *Pachypora*. The genus occurs both in the Lower and Middle Devonian. There is also no doubt about the *Cladochonus*, and whether it is referable to *C. alternans* (Römer) or to *C. Schlüteri* (Holz.) matters little, for the genus does not occur in the Lower Devonian, ranging from Middle Devonian to Carboniferous; consequently its occurrence is antagonistic to his opinion regarding the age of the fauna.

Lastly, there are two specimens of *Fenestella* to which Mr. Whidborne gave the name of *torwoodensis*, remarking that "it comes extremely close to" the *F. arthritica* (Phil.) from Hope's Nose. To me it seems really closer to his *F. fanata* from Lummaton, and either way its affinities are with the Middle Devonian forms.

Part II. By R. B. Newton, F.G.S.[1]

The following is a revised list of the fossils from the site of the Torquay Museum, based on a study of the specimens forwarded by Mr. Jukes-Browne. These were believed to include the specimens described by Mr. Whidborne in 1901, as well as a few which had not been examined by him. The Cephalopoda have been determined by Mr. G. C. Crick. The name of Etheridge appended to notes on the distribution of the species refers to that author's *Fossils of the British Islands. Palæozoic*, 1888.

Cephalopoda.

Anarcestes lateseptatus, Beyrich, sp.

This is essentially a Middle Devonian species and does not occur in the Lower Devonian. In Germany it ranges from the Orthoceras shales of Wissenbach (Untere Mittel-Devon) to the upper part of the stage (Obere Mittel-Devon) according to Holzapfel (Abhand. Kön. Preuss. Geol. Landesanstalt, 1895). In England it is common in the bands of shaly limestone which occur in the lower part of

[1] Published by permission of the Trustees of the British Museum.

the Calceola Shales of Mudstone Bay, south of Berry Head, and is associated with *Cyrtoceras bdellalites*, Phil., and *Gyroceras ornatum*, Goldf. (See Ussher, *Geology of the Country around Torquay*, Mem. Geol. Surv., 1903, p. 76.)

ORTHOCERAS SPECIOSUM, Münster.

O. cinctum, Phillips, *non* J. de C. Sowerby.
O. hercynicum (?), Whidborne, GEOL. MAG., 1901, *non* Kayser.

There are three fragments of this species.

Distribution.—Middle and Upper Devonian.

ORTHOCERAS sp.

This is the specimen which according to Mr. Whidborne may possibly belong to *O. ellipticum*, Münster. There is only one fragment, and it shows a central siphuncle.

Distribution.—According to Dr. A. H. Foord, *O. ellipticum* occurs in the Upper Devonian of Germany.

Gasteropoda.

CAPULUS PRISCUS (?), Goldfuss, sp.

Determined and figured by Mr. Whidborne in GEOL. MAG., 1901, p. 534, Pl. XVIII, Fig. 1.

Only this one and the top of what seems to be a second specimen have been seen.

Distribution.—Lower and Middle Devonian.

BELLEROPHON cf. MUNDUS, Whidborne.

See Devonian Fauna, Mon. Pal. Soc., 1892, p. 327, pl. xxxi, fig. 9.

The only example is a fragmentary cast which resembles this species, but it is not mentioned in GEOL. MAG., 1901.

Distribution.—Middle Devonian.

Brachiopoda.

ATHYRIS CONCENTRICA, von Buch, sp.

See Whidborne, GEOL. MAG., 1901, p. 534, Pl. XVIII, Fig. 6.

The example seen is that which was figured by Mr. Whidborne, and is a small rather obscure cast. We have not been able to find the mould mentioned by him as showing the "characteristic strong concentric ridges".

Distribution.—Lower Devonian (Coblencian = France and Germany), Middle Devonian (from base to top), Upper Devonian (Etheridge).

CLORINDA BREVIROSTRIS, Phillips, sp.

The *Pentamerus brevirostris* of authors.

A single example of this species has been detected. It was not mentioned by Whidborne, but was recorded by Davidson from Hope's Nose, near Torquay.

Distribution. — Middle Devonian only (England, France, and Germany).

GYPIDULA GALEATA, Dalman, sp.

Pentamerus galeatus of most authors and of Whidborne in GEOL. MAG., 1901, p. 535, Pl. XVIII, Figs. 4, 5.

This is the prevailing fossil of the bed from which the collection was made. A large number of examples were obtained, most of them being crushed and flattened, sometimes from front to back and sometimes from side to side, but a few occurring in harder ferruginous lumps or concretions preserve much of their original convex character.

Distribution.—Silurian to Middle Devonian.

LEPTÆNA RHOMBOIDALIS, Wilckens, sp.

This species was recorded by Mr. Whidborne and five specimens have been seen.

Distribution.—Silurian to Upper Devonian and Carboniferous.

ORTHIS INTERLINEATA, J. de C. Sowerby.

This species was not recorded by Whidborne and seems to be rare, for only two examples have been seen.

Distribution.—Middle and Upper Devonian (Etheridge).

ORTHOTETES UMBRACULUM, Schlotheim, sp.

Recorded and figured by Whidborne in GEOL. MAG., 1901.

The figured specimen and seven other fragments exist.

This species is regarded by Dr. Ivor Thomas as belonging to his genus *Schellwienella* (*The British Carboniferous Orthotetinæ*: Mem. Geol. Surv. Gt. Britain, 1910, Palæontology, vol. i, pt. ii, p. 97).

Distribution.—Lower to Upper Devonian (Etheridge).

SCHIZOPHORIA STRIATULA, Schlotheim, sp.

Hysterolithus, Linnæus, Museum Tessinianum, 1753, pl. v, figs. 2, *non* figs. 1.
Anomia hysterita, Linn. Syst. Naturæ, 1758, 10th ed., p. 703, *pars*.
Orthis hysterita, Gmelin, in Whidborne, GEOL. MAG., 1901, p. 536.
O. aff. *Monnieri*, Rouault, in Whidborne, op. cit.

Having examined the original figures of Linnæus in his Mus. Tess. I find that figures No. 2 represent internal casts of the form which Schlotheim subsequently called *Terebratulites striatulus*, while figures No. 1 portray a different species, for which the name *hysterita* should be retained. The Torquay specimens are *striatula*.

Distribution.—*Orthis hysterita* is recorded by Kayser from the Lower Devonian of Germany, and this may be the true *hysterita*, but *O. striatula* has not been recorded from the Lower Devonian. On the other hand, it occurs frequently in the Middle and in the Upper Devonian of England, France, and Germany (*teste* Davidson, Haug, and Holzapfel).

SPIRIFER CURVATUS, Schlotheim, sp.

Recognized and figured by Whidborne, GEOL. MAG., 1901.

Several specimens of this species occur, including that figured by Whidborne, but they are all more or less crushed. Two of them are impressions of the outer surface and show the characteristic ornamentation.

Distribution.—Lower and Middle Devonian.

SPIRIFER SPECIOSUS, Schlotheim, sp.

S. costatus, J. de C. Sowerby, Trans. Geol. Soc. Lond., 1840.

Two examples of this species occur, and are probably those which Mr. Whidborne took for *S. primævus*, Steininger. The latter, however, is a more quadrate form than the Torquay specimens, which agree with casts of *S. speciosus.*

Distribution.—Lower Devonian (Coblencian) and Middle Devonian, but rare above the Eifelian (Calceola Shales).

SPIRIFERINA INSCULPTA, Phillips, sp.

This species was not recorded by Mr. Whidborne, but there are three pieces of slate bearing the number 15 which contain well-preserved fragments of it showing details of the sculpture and also two internal casts which are probably of the same species.

Distribution.—Middle Devonian to Carboniferous.

STROPHEODONTA INTERSTRIALIS, Phillips, sp.

St. nodulosa, Whidborne (*non* Phillips), Dev. Fauna, Mon. Pal. Soc., vol. ii, pl. xvi, figs. 8–10, 1893. Figs. 6 and 7 of the same plate may represent *Leptæna nodulosa* of Phillips, which Davidson has regarded as synonymous with *L. rhomboidalis.*

St. tæniolata, Whidborne (*non* Sandberger), GEOL. MAG., 1901, p. 537, Pl. XVIII, Figs. 8, 9.

The Torquay specimens cannot be identified with the *St. tæniolata* of Sandberger, but they exhibit radial costæ identical with those seen on the shells figured as *St. nodulosa* from the Middle Devonian limestones of Lummaton and Wolborough. This form I regard as only a variety of *St. interstrialis*, Phil., the typical form of which also occurs in the same limestones. Sandberger's *tæniolata* differs from *interstrialis* of Phillips in being of more oval and semicircular contour, in the length and width showing equal measurements, and in its possession of a far greater number of primary costæ.

Distribution.—Middle Devonian only (Etheridge).

Crustacea.

PHACOPS cf. SCHLOTHEIMI, Brown, sp.

A tail (minutely granulated), a head, and other fragments in the matrix belong to a species of *Phacops.* There is also part of another head and a large thorax. The eyes are certainly larger than the typical form of *Ph. latifrons*, and as Mr. Whidborne pointed out they contain eight lenses in a row, whereas *latifrons* has only five or six and *batracheus*, Whidborne, has only four or five. His identification may therefore be retained, but it makes no difference in regard to comparative age, as *Ph. Schlotheimi* is essentially Middle Devonian, occurring both in the Calceola Shales (Eifelian) and in the *Stringocephalus* limestones (Givetian).

The material forwarded from Torquay did not include any specimens which could be identified with *Conocardium cuneatum*, Römer, or *Atrypa reticularis*, of which Mr. Whidborne recorded single examples. [Note by A. J. J.-B.: The material in my hands has again been searched for anything which might be referable to either of these species, but without success.]

Conclusions.

The four fossils identified by Mr. Whidborne with species which were essentially Lower Devonian or Coblencian were those regarded as *Orthoceras hercynicum*, *Spirifer primævus*, *Orthis hysterita*, and

Strophomena tæniolata. From the preceding notes it will be seen that the *Orthoceras* is now identified as *O. speciosum*, Münster (a Middle and Upper Devonian form); that the record of *Spirifer primævus* was probably based on the casts of *S. speciosus*; that the true *Orthis hysterita*, Linn., does not occur, the form in question being the *O. striatula* of Schlotheim. Finally, the species regarded by Mr. Whidborne as *Stropheodonta tæniolata* must be identified with a variety of *St. interstrialis*, Phil., a well-known Middle and Upper Devonian species.

Thus the testimony which seemed to turn the scale in favour of a Lower Devonian age for the fauna has completely vanished, while strong new evidence for its being of Middle Devonian age has been discovered in the recognition of *Anarcestes lateseptatus*, *Orthoceras speciosum*, *Bellerophon mundus*, *Clorinda brevirostris*, *Orthis interlineata*, *Schizophoria striatula*, *Spiriferina insculpta*, and *Stropheodonta interstrialis* (var. *nodulosa*).

The following table shows the range of the species as now identified, and makes it certain that the affinities of the fauna are with the Middle and not with the Lower Devonian. All the species which have been identified with previously known forms occur in the Middle Devonian, either of this country or of Germany, while only seven of them have also been found in the Lower Devonian.

Names.	Silurian.	Lower Devonian (Coblencian).	Middle Devonian (Eifelian).	Upper Devonian.	Carboniferous.
Anarcestes lateseptatus, Beyrich			x		
Orthoceras speciosum, Münster			x	x	
Orthoceras sp.					
Capulus priscus, Goldfuss		x	x		
Bellerophon cf. *mundus*, Whidborne			x		
Athyris concentrica, von Buch		x	x	x	
Clorinda brevirostris, Phillips			x		
Gypidula galeata, Dalman	x	x	x		
Leptæna rhomboidalis, Wilckens	x	x	x	x	x
Orthis interlineata, J. de C. Sowerby			x	x	
Schizophoria striatula, Schlotheim			x	x	
Orthotetes umbraculum, Schlotheim		x	x	x	
Spirifer curvatus, Schlotheim		x	x		
S. speciosus, Schlotheim		x	x		
Spiriferina insculpta, Phillips			x		x
Stropheodonta interstrialis, Phillips			x		
Phacops Schlotheimi, Bronn			x		
Aulacophyllum looghiense, Schlüter			x		
Duncanella cf. *major*, Schlüter			x		
D. cf. *pygmæa*, Schlüter			x		
Cladochonus Schluteri, Holzapfel			x	x	
Pleurodictyum pachyporoides, Whidborne					
Metriophyllum (?)					

VI.—Saturation of Minerals.

By Alexander Scott, M.A., B.Sc.,
Carnegie Research Scholar of the University of Glasgow.

In a recent paper [1] Professor Shand put forward a plea for the more careful consideration, in rock classification, of the saturated or unsaturated state of the constituent minerals. The criterion of saturation which is assumed is the capability of co-existence with some form of free silica, as shown by the "observed facts of distribution". By means of this criterion, the rock-forming minerals are divided into two groups—the saturated minerals and the unsaturated ones. The former group includes the felspars, amphiboles, pyroxenes, micas, and most of the so-called accessory minerals, as well as those of pneumatolytic origin; while the latter group comprises the felspathoids, olivine, the spinels, corundum, and the garnets (except spessartite, which is put into the first class). Rocks are divided into three classes, according as they are made up wholly of saturated minerals, partly of saturated and partly of unsaturated ones, or wholly of unsaturated ones.

The criterion is so obvious that it has been implicitly used, at least in part, in most of the classifications proposed since Zirkel's [2] in 1866. In the American Quantitative Classification, for example, the ratio of felspar to lenad (felspathoid) takes second place only to the ratio of salic to femic minerals in determining the position of a rock.[3] The 'class' is determined by the latter ratio and the 'order' by the former. In practically all cases, however, the application of this idea has not extended beyond the discrimination of the felspar and felspathoid-bearing rocks, and what Professor Shand advocates is the extension of the principle to the other minerals of igneous rocks. There are, however, certain inherent difficulties in such a general application, and it is now proposed to consider, very shortly, some of these difficulties.

The first question which arises is whether the method of determining which minerals are saturated and which are not, is sufficiently exact. The distribution of minerals in igneous rocks, apart from all consideration of the history of the rocks, seems to be rather too empirical to be used as a satisfactory criterion. For example, olivine must be included in the list of unsaturated minerals, and yet it occurs along with quartz in a number of rocks. In addition to those mentioned by Professor Shand, several rhyolites in America [4] and elsewhere [5] contain olivine and tridymite, while the author has described pitchstone-porphyries from Arran [6] containing phenocrysts of olivine and quartz. In the former case the minerals occur in lithophysæ and may have had a hydrothermal origin after the consolidation of the rock, while in the latter the olivine is probably xenocrystic. Quartz-dolerites are usually supposed to have caught up

[1] "On Saturated and Unsaturated Rocks": Geol. Mag., Dec. V, Vol. X, pp. 508–14, 1913.

[2] *Lehrbuch der Petrographie*, Bd. i, p. 450, 1866.

[3] *Quant. Class. of Igneous Rocks*, 1903, p. 123 et seq.

[4] e.g. Iddings, Amer. Journ. Sci., ser. III, vol. xxx, pp. 58–60, 1885.

[5] Iddings & Penfield, ibid., ser. III, vol. xl, pp. 75–8, 1890.

[6] "Pitchstones of South Arran": Trans. Geol. Soc. Glasgow, vol. xv, pp. 19–37, 1913.

siliceous material which remains partly undissolved, while the quartz basalts of California [1] have been explained as due to the intratelluric mixing of a dacite and basalt. This explanation has not been fully accepted,[2] although the presence of a reaction-rim round the quartz crystals indicates their probable xenocrystic origin.

There are two possible ways, however, in which primary quartz (or other silica mineral) may be formed in unsaturated rocks in small quantities. If water be present in a magma consisting mainly of metasilicates, the hydrolitic action of the water vapour or its dissociated constituents at high temperature may cause the metasilicates to partly break up into orthosilicate and free silica, and the latter may finally crystallize as quartz or tridymite.

The other possibility is that the reaction

$$\text{olivine} + \text{silica} \longrightarrow \text{enstatite}$$

may be appreciably reversible. It is most probable that all chemical reactions are theoretically reversible, though, in many cases, under suitable conditions a reaction can proceed so far in one direction that the reverse reaction cannot be detected. Since practically all chemical reactions involve an absorption or evolution of heat, it follows that one of the actions in a reversible reaction is, in general, endothermic and the other exothermic, and we can deduce, thermodynamically, that a rise in temperature displaces the equilibrium position in such a way that the endothermic reaction receives the greater acceleration. The formation of a metasilicate by the interaction of silica and an orthosilicate is exothermic, and the reverse reaction is therefore endothermic and will proceed to a greater extent the higher the temperature. Thus the possibility of silica minerals separating from a part-saturated rock will be greater when the crystallization takes place at a high temperature than when it occurs at a lower one.[3]

The disadvantages of a criterion such as this empirical one of 'saturation', and indeed of all similar empirical ones, become more manifest when the stability relations of the minerals in a rock are considered. So many factors, external and internal, influence the cooling of a rock, that in many cases the resultant solid is not in a condition of maximum stability, and one function of a rational classification should be to indicate in what way, and to what extent, there is deviation from a state of equilibrium. For instance, many rocks show evidence of undercooling, not only with regard to the passage from the liquid to the solid state, but also with regard to transformations in the solid state. Thus glass is not a true solid but merely an undercooled liquid, and, as such, is a metastable phase at ordinary temperatures. Devitrification, i.e. the transformation to the more stable crystalline form, follows, in accordance with the Principle of Maximum Work, the glass having a higher potential than the solid.

[1] Diller, Bull. U.S. Geol. Surv., 1891, No. 79, pp. 21–33.

[2] Cf. Iddings, Bull. U.S. Geol. Surv., 1890, No. 66, pp. 20–32.

[3] Since this was written, Bowen & Andersen (Am. Journ. Sci., ser. IV, xxxvii, pp. 487–500) have described experiments which show that on cooling a melt of the composition $MgO{-}SiO_2$, some forsterite separates out first and then the residual liquid crystallizes as a mixture of silica and clinoenstatite.

The comparative rarity of leucite may be explained in a similar way. This mineral seems to form only in a small temperature interval,[1] and if, by undercooling or otherwise, crystallization takes place outside this interval, the final product is a mixture of orthoclase and nepheline. This may also be expressed by saying that the reaction

$$\text{kaliophilite} + \text{orthoclase} \leftrightharpoons \text{leucite}$$

is reversible, and proceeds towards the formation of leucite only through a certain temperature range.

In this case, the effect of undercooling is not merely physical but chemical also, and is therefore analogous to the phenomena observed in the cadmium-antimony alloys.[2] A mixture of equal atomic percentages of cadmium and antimony, cooling from the fused state, deposits crystals of a compound Cd Sb, if the melt is inoculated; otherwise, without inoculation, undercooling takes place and a mixture of antimony and a compound $Cd_3 Sb_2$ separates. The freezing-point curve of the metastable system therefore differs from that obtained under conditions of stable equilibrium. The system albite-(soda)-nepheline is probably similar, save that the compound, analcite, requires the presence of water before it is formed, in addition to definite conditions of temperature and pressure.

Undercooling, however, may take place in the solid state as well as in the liquid state, and involve the presence of unstable or metastable phases. Instances of this phenomenon are common amongst the rock-forming minerals, silica itself being a good example. According to recent work,[3] β-cristobalite is the modification of silica stable above 1,470°; β-tridymite, between 870° and 1,470°; β-quartz between 575° and 870°; and α-quartz below 575°. The occurrence of tridymite in certain effusive rocks, such as the trachyte of Drachenfels, is well known, and it will be obvious from the above that the mineral must be an unstable phase. Its origin may be due to crystallization from the magma at a temperature above the transition-point, and then owing to the rapid cooling, the transformation to quartz may be inhibited. It is possible, however, as Fenner[4] has pointed out, that crystallization may have occurred below 870°, and that an unstable form has developed in accordance with Ostwald's rule, that the most stable phase may not be attained directly, but that phases of intermediate stability may first form. As in the first case, a rapid fall to ordinary temperatures might greatly reduce the velocity of inversion. There are apparent exceptions to Ostwald's rule, but it is possible that these may be explained by the thermodynamic potential of the liquid at the given temperature being lower than, or nearly equal to, the potential of the modifications which fail to appear. In the case of tridymite, quartz, etc., the change is apparently physical and is confined to a polymorphic transformation.

The hornblendes and pyroxenes may constitute another example of the same type. While there is still some obscurity regarding the

[1] Cf. Washington, Journ. Geol., xv, pp. 257–79, 357–95, 1907.

[2] Kurnakov & Konstantinov, Zeit. anorg. Chem., lviii, pp. 12–22, 1908.

[3] Fenner, "The Stability Relations of the Silica Minerals": Amer. Journ. Sci., ser. IV, xxxvi, pp. 331–84, 1913.

[4] Fenner, loc. cit., p. 342.

relations of these two groups, the evidence both of petrography and of synthetic work[1] is in favour of pyroxene being the high temperature form and hornblende the low temperature one. In the diorites and gabbros, hornblende often appears as a parallel growth on pyroxene, and many cases have been described of the former mineral containing cores of the latter.[2] Similarly augite is often found pseudomorphed by hornblende. It has been argued against this view that the hornblende, and the pyroxene from which it forms, have different compositions, particularly where the alteration has been aided by pressure, as in the formation of hornblende schist by the alteration of a dolerite.[3] This difference, however, is probably due to the fact that these minerals are capable of combining many molecules in solid solution, and that this capability varies with the conditions of crystallization. Thus, at Garabal Hill,[4] the margin of an intrusion is a hornblende diorite with about 30 per cent of hornblende, and the centre, a few feet distant, is a hornblendite with 85 per cent of hornblende, while the composition of the two rocks is approximately the same. The cases of alteration of hornblende into pyroxene would seem to be explained by reheating due to later intrusions,[5] or to some similar cause.

Another change which may take place in the solid state is the breaking up of a solid solution on cooling. Vogt[6] describes the separation of augite from solid solution in enstatite and also ascribes this origin to some perthitic growths.[7]

So far, only the effect of temperature on the formation of stable minerals has been considered. The conditions of pressure, however, also exert a considerable influence, particularly in many plutonic rocks. When an igneous rock contains minerals which are generally of metamorphic origin, it is assumed that these have formed under pressure. For example, garnet is a typical product of metamorphism, and when it does occur in a plutonic rock it has probably crystallized under high pressure. In the case of the Charnockite Series, the garnet seems to have originated in this way, as there is other evidence of the rocks having undergone dynamic action,[8] while the eclogites in many cases show similar effects.[9] Fermor[10] postulates for the formation of kodurite, an infra-plutonic zone of garnet-bearing rock.

The evidence of synthetic work is likewise in favour of garnet forming only under particular conditions of pressure and probably

[1] Allen, Wright, & Clement, Amer. Journ. Sci., ser. IV, xxii, pp. 385–438, 1906; Allen & White, ibid., ser. IV, xxvii, pp. 1–47, 1909; Doelter, *Neues Jahrbuch*, 1897, pt. i, pp. 1–26.

[2] Cf., for example, Allport, Q.J.G.S., xxxv, pp. 637–42, 1879; Wyllie and Scott, GEOL. MAG., Dec. V, Vol. X, pp. 499–508, 536–45, 1913.

[3] Teall, Q.J.G.S., xli, pp. 133–44, 1885; see also Harrington, Rec. of Progress. Geol. Surv. Canada, 1877–8, p. 21 G.

[4] Wyllie & Scott, loc. cit.

[5] Cf. Lacroix, *Minéralogie de la France*, i, pp. 668–9, 1895.

[6] Q.J.G.S., lxv, pp. 100–1, 1909.

[7] Tscher. Min. u. Pet. Mitt., xxiv, pp. 537–42, 1905.

[8] Holland, Mem. Geol. Surv. India, xxviii, pp. 117–249, 1898.

[9] Cf. Hezner, Tscher. Min. u. Pet. Mitt., xxii, pp. 437–505, 1903, for origin of eclogites.

[10] Rec. Geol. Surv. India, xlii, pp. 208–30, 1912; xliii, pp. 41–7, 1913.

in a narrow temperature range. Numerous observers[1] have reported that garnet, on fusion, breaks up and finally recrystallizes as a mixture of other minerals such as anorthite, monticellite, melilite, etc. Attempts to synthesize garnet have not met with much success, though the formation of the mineral has been reported in a few cases.[2] Hence we may assume that if a rock containing garnet had crystallized by a normal cooling process, under ordinary pressures, garnet would be entirely replaced by other minerals. In some cases it is probable that some of the minerals did not form under such high pressure as the garnet, and hence the latter would be liable to undergo resorption by the residual liquid magma. The well-known celyphite border which occurs round pyrope crystals in peridotites may arise in this way by the action of a liquid residual magma on the pyrope, under pressures much lower than those at which the latter form and therefore under conditions which would render pyrope an unstable phase.

Thus it will be seen that there are grave objections to the garnets being considered as saturated or unsaturated in the way felspar or nepheline might be. If spessartite be considered as saturated merely on account of its co-existence with quartz in certain rocks, and the other garnets as unsaturated on account of the absence of this property, the result would be, not only to divide closely related garnet rocks into two widely different groups but also probably to class each with rocks from which they might differ considerably both in chemical and mineralogical composition. The conclusions of Boeke[3] render it very improbable that spessartite differs essentially from the other garnets, as he finds that almandine forms a continuous series of solid solutions, with both spessartite and pyrope, and that grossularite and andradite form a similar series. The two latter, however, form with each of the others systems which conform to Roozeboom's fifth type, as does also the system pyrope-spessartite, two limited series of solid solution being formed. Any differences which do exist, are likely to occur between those minerals which give systems of the latter type, but such differences, if any, would probably be physical. Similar objections exist with regard to the micas, which also seem to form generally under particular conditions of pressure and temperature.

Although the hornblendes and pyroxenes are found along with quartz, it is probable that the members of these groups which contain the sesquioxides—alumina and ferric oxide—can react with free silica under certain conditions. The most generally accepted explanation of the presence of these oxides is that they occur in molecules of the type $R'' Al_2 Si O_6$ (Tschermak's silicate), where R is ferrous iron or magnesium, which molecules are obviously unsaturated with respect to silica. Harker[4] explains certain phenomena of differentiation as due to a reaction taking place between diopside and

[1] Bourgeois, Annales Chim. Phys., ser. V, xxix, p. 458, 1883; Vogt, *Mineralbildung in Schmelzmassen*, 1892, pp. 186–8, etc.
[2] Gorgeu, Annales Chim. Phys., ser. VI, iv, pp. 536–53, 1885.
[3] Boeke, *Zeit. Kryst. Min.*, liii, pp. 149–57, 1913.
[4] *Geol. Small Isles* (Mem. Geol. Surv. Scotland), 1907, p. 91.

Tschermak's silicate with the production of olivine and anorthite. Again, minerals such as tourmaline and topaz are usually the result of pneumatolytic or fumarolic action, and as such it is impossible to deduce from their co-existence with silica in rocks that they would form during the normal cooling of an 'acid' magma.

From what has been said above it is obvious that a classification of igneous rocks can no longer be made dependent on such a factor as saturation with respect to silica, particularly when applied in this empirical fashion. During the period of cooling, rocks are subjected to many vagaries, owing to the impossibility of the external conditions being uniform, and any classification dependent on the final mineralogical composition without reference to the 'cooling-history' is not of much use. Any group of igneous rocks must be subdivided according to the method of development of the particular rocks, and it is impossible to compare directly on a purely modal basis a rock which has formed through a normal cooling process and is therefore in a state of equilibrium and one which is not in equilibrium owing to such causes as undercooling, inhibition of transformation either in the liquid or solid states, or the formation of some or all of the constituent minerals under abnormal conditions of pressure and temperature. In rocks of similar composition, the minerals which develop in the latter case are often widely different from those arising in the former one, and hence such minerals as the garnets, topaz, etc., cannot be said to be 'saturated' or 'unsaturated' in the sense that albite, nepheline, or leucite can be. Similar objections exist with regard to a classification on a basis of the chemical composition or of the 'norm' derived from it, and one of the chief advantages of the American system is that it provides an extremely good method of indexing the increasing volume of rock analyses.

These two factors, however, the chemical and mineralogical composition, are the only ones we have for a basis in classification, but they must be correlated in such a way that as much information as possible is obtained regarding the 'cooling-history' of the rocks. The crystallization of rocks can no longer be considered either as wholly fortuitous, or as wholly the result of a normal cooling process, but as the result of the operations of the laws of physical chemistry. Hence the objects of a rock classification must be to correlate rocks not only of similar chemical composition but also with similar 'cooling-histories'.

The data for this can be derived from (*a*) the determination of chemical composition, (*b*) of mineralogical composition, (*c*) the field relations of the rocks, (*d*) the evidence of synthetic work in mineralogy. The defects of most of the current classifications can be traced to the position of paramount importance given to some one of these bases and to the subordinate positions assigned to the others. The occurrence of minerals in rocks, as shown by the 'observed' facts of distribution, must be correlated with the other evidence—particularly that of field relations and of synthetic work — concerning the conditions of equilibrium both during the cooling process and in the solid phases observed in the rock. It is only in this way that we can acquire a knowledge of the genetic relationships and the general history of igneous rocks.

REVIEWS.

I.—Fossil Crustacea.

1. E. Stolley. Ueber zwei neue Isopoden aus nord-deutschen Mesozoikum. 3 Jahresber. d. niedersächsischen geol. Ver. zu Hannover, 1910 [? 1913], pp. 191–216, Taf. vi.
2. Ph. C. Bill. Ueber Crustaceen aus dem Voltziensandstein des Elsasses. Mitth. d. geol. Landesanstalt von Elsass-Lothringen, Bd. viii, Hft. iii, pp. 289–338, Taf. x–xvi, 1914.

1. Fossil remains of Isopoda are so rare and so little known that considerable interest attaches to Herr Stolley's detailed description of two new species, *Palæga jurassica* from the Middle Jurassic (Dogger) near Harzburg, and *Urda cretacea* from the Middle Gault of Hannover. The genus *Palæga* has not hitherto been recognized earlier than the Cenomanian, but the author very justly points out that the name covers an assemblage of more or less incompletely known forms which may not be strictly congeneric. It may be added there is very little reason for supposing that any of these forms belong to the family Ægidæ in the sense in which it is understood by modern zoologists, and that the presence of ocelli on the dorsal surface of the head in the new species, if it were confirmed, would be a character of far more than the trifling importance which the author attributes to it. The second species, *Urda cretacea*, is referred to a genus hitherto known only from the Kimmeridgian of Solenhofen, and is described from a specimen in which the segmentation of the body is more perfectly preserved than in the case of the earlier forms. No new light, however, is thrown upon the affinities of the genus. Here, as elsewhere, it seems possible that something might result from a more extended comparison with recent forms.

2. Herr Bill has had the good fortune to discover, in the Upper Bunter of Alsace, a Crustacean fauna hitherto practically unknown, although one or two forms were very incompletely described long ago by H. von Meyer and others. Three of the new species are referred to the Decapoda, and are of special interest as being among the very earliest forms that can with certainty be attributed to that order. The new genus *Clytiopsis*, in which two of the species are placed, belongs to the tribe Nephropsidea, which includes the recent Lobsters and Crayfishes, and of which the oldest representative has hitherto been the Liassic *Eryma*. The material was sufficiently well preserved to enable the structure not only of the body but also of a good many of the appendages to be described with considerable detail. The third Decapod is one of the Penæidea, and is referred, provisionally, to the genus *Penæus*.

A new genus *Schimperella*, with two species, is based on some finely preserved material which has rendered possible a fairly complete account of its structure. It is referred to the 'Schizopoden', by which name, apparently, the author means only the Mysidacea. It seems highly probable, although no brood-pouch has been detected, that *Schimperella* really does belong to this order, of which no representatives have hitherto been discovered to link the Carboniferous forms with those now existing.

The other Crustacea described in this memoir are of less general interest. *Triasocaris* is established as a new genus, and is included in the Syncarida with an expression of doubt that seems to be quite justified. A preoccupied name, *Diaphanosoma*, has been chosen for another new genus, based on what the author thinks may be a larval form of one of the Decapods. An *Estheria* is described which, by a rare exception, shows traces of the body and some of the limbs. Finally, *Limulites Bronni* is redescribed, and a misprint in Schimper's original account is corrected, thereby reducing to one-tenth the measurements which had led subsequent writers to attribute to this species the relatively gigantic total length of $1\frac{1}{2}$ metres.

W. T. Calman.

II.—Geology of the Province of Yünnan in Western China.

During the years 1907–10 several traverses were made by J. Coggin Brown, M.Sc., between Bhamo and Têng-yüeh in the province of Yünnan, the results of which are described in a series of short papers.[1]

The greater part of the area is occupied by a series of gneisses, mica-schists, and crystalline limestones with some intrusive granites. At one locality there is a small development of quartzites and phyllites probably belonging to the Kao-liang Series of Upper Burma. Farther to the east rocks of Ordovician and Silurian age occur. The fossils from these beds have been identified provisionally by F. R. Cowper Reed, M.A.

In the neighbourhood of Têng-yüeh there are four groups of extinct volcanoes. The rocks extruded from these volcanoes are described by R. C. Burton, B.Sc. They belong to three periods: (1) older bedded pyroxene-andesites; (2) massive augite-andesites, some of which are olivine-bearing and grade into olivine-basalts; with these are associated some augite-enstatite-andesites and hornblende-andesites containing nepheline; (3) olivine-basalts. The last stages of vulcanicity are represented by groups of hot springs. The volcanic rocks are probably of late Tertiary age.

Mr. Burton notes that these volcanoes lie on the line joining Barren Island, Narcondam, and Mount Popa (Burma) with Loi-han-hun in the Northern Shan States. This line is itself a continuation of the Sunda volcanic chain running through Java and Sumatra. The rocks extruded by volcanoes along this line are petrographically similar, consisting of augite-andesites, some hornblende-andesites, and olivine-basalts. The presence of nepheline in some of the rocks of Yünnan is interesting, but it appears to be a rare constituent, and its presence in such quantities cannot, as Mr. Burton thinks, be regarded as placing these rocks in the alkali series, nor need it indicate the proximity of an "Atlantic province". It is interesting to note that in Yünnan, as at so many other centres of vulcanicity, the last lavas to be extruded are olivine-basalts.

In some parts of the area, notably in the plains of Kan-ngai and Nan-tien, there are extensive lacustrine deposits; these are partly of late Tertiary age, but in places deposition is still going on.

[1] Records of the Geological Survey of India, vol. xliii, 1913, pp. 173, 206, 327.

Some interesting changes in the course of the Irrawaddy near Bhamo are noted. These are apparently due to the cutting back of tributaries, assisted by great differential earth-movements.

These papers are illustrated by thirteen plates and one geological map on a scale of 4 miles to the inch.

III.—Petrographical Provinces and the Sequence of Types.

SOME very important criticisms of the wider generalizations of modern petrology were made by Henry S. Washington in a paper read before the International Geological Congress in 1913 on "Volcanic Cycles in Sardinia".

The Sardinian volcanoes belong to three different volcanic cycles. A careful study of the sequence of the various lava-flows brings out the following points. The sequence as a whole is discontinuous but recurrent. The close of one magmatic cycle is simultaneous with the ending of one volcanic phase, and the recurrence of a new one coincides with a change in the intensity or character of the vulcanicity. In the several successive cycles there is a progressive decrease in differentiation; thus the earliest cycle comprises rhyolites, trachytes, andesites, and basalts; while in the latest felspar-basalts are the only lavas which have been extruded. Each cycle closes with the extrusion of felspar-basalt. The sequence here observed is not in accordance with the 'law' of divergence from an average magma. Harker would, however, regard such exceptions as due to the suppression of one of two divergent lines.

The author points out that the sequence must depend on such factors as the form of the magma basin, the point at which this is tapped, and the character and amount of the volatile constituents which escape, so that it may be questioned whether the sequence of types really possesses the great importance usually attributed to it. For most volcanic regions it appears that the sequence of types varies somewhat with the character of the regional magma, but nearly always closes with basaltic rocks. The coincidence of the several cycles with discontinuity of volcanic activity, which is so well shown in Sardinia, is also observed at Pantelleria and in many other areas of vulcanicity; on the other hand, there are cases, as at Santorin, where lavas extruded at different periods are practically identical in composition.

The lavas of Sardinia furnish another of the now numerous instances of the association in the same volcano of the so-called 'Atlantic' and 'Pacific' types. It seems impossible to refer all rock types to only two lines of variation. The concentration of a very large number of rock analyses round several types indicates that there has been one general earth-magma. The magmas which characterize different petrographical provinces must have been derived from this general magma by differentiation *in all possible directions*. Attention must be paid to magnesic, ferrous, and potassic magmas, and not only to sodic ones. At present far too much importance is attached to the occurrence of such minerals as ægirite and nephelite, even when present in quite small amount, while the presence, for instance, of potash in biotite is often neglected.

The data at present available are insufficient for even the broadest generalizations. Petrologists must recognize the need of quantitative data, of adequate chemical analyses, and of the complete collection of data in the field. Only thus can they hope for the successful application of the principles of physical-chemistry to the solution of the complex problems of petrology.

IV.—Bulletin of the Seismological Society of America.

In the issue for March, 1914 (vol. iv, No. 1), a useful epitome of the seismological work of John Milne is given by Comte de Montessus de Ballore.[1]

A brief historical account of Milne's life-work, in which it is pointed out that he was always a decided partisan of the tectonic or geologic origin of earthquakes, forms an introduction to an admirably arranged bibliography of Milne's papers. The fourteen heads under which the references are grouped greatly facilitate the selection of those which deal with any particular branch of the subject of seismology, and in every case notes, giving a general idea of the contents, are appended to those of most importance.

Under separate headings we find a record of papers on geographical and geological points of view, volcanoes, internal heat and state of the globe, and other aspects of the subject.

This analysis of Milne's work should prove valuable to all who are interested in any of the numerous branches of seismological investigation.

V.—The Cotteswold Naturalists' Field Club.

The Proceedings for December 1913, being pt. ii of vol. xviii, contain a record of the excursions and meetings of this Club during 1913. Visits were paid to Tidenham Chase and Tintern, the Sherborne district of Dorset, Wotton-under-Edge, and other interesting localities. Mr. L. Richardson contributes a geological map, on the 6 in. scale, of the southern part of Cheltenham and the adjoining country, which shows the distribution of both the superficial and solid rocks. The unusual colour-scheme adopted is somewhat confusing, although in other respects the map is quite clear. Twelve pages of text are given in explanation of the sheet. A map of the northern part of Cheltenham, with explanation, was published in pt. iii, vol. xvii, of the Proceedings of the Club. Professor Lapworth discusses the origin of the boulders collected in the grounds of Bournville, Birmingham, and gives a brief sketch of the glaciology of the Midlands. An account of the water supply of Cirencester is given by T. Hibbert and L. Richardson; the latter also records the details of a deep boring at Kemble passing through 353 feet of strata from Great Oolite to Upper Lias.

[1] A life of Professor John Milne, F.R.S., with his portrait and a list of his published works, appeared in the Geol. Mag. for August, 1912, pp. 337–46; his death was recorded (July 31, 1913) in the Geol. Mag., September, 1913, p. 432.

VI.—Brief Notices.

1. New Periodical.—The first volume of the Mémoires de l'Institut Géologique de l'Université de Louvain, published under the editorship of Henry de Dorlodot, has recently appeared. A quarto, printed in large type and well illustrated, it makes an imposing volume. It contains three papers: Asselbergs, "Le Dévonien inférieur du Sud-Est de l'Ardenne Belge"; Salée, "La groupe des Clisiophyllides"; and Wong Wen-Hao, "La Porphyrite quartzifère de Lessines." Other volumes will appear according to material in hand.

2. Triassic Fauna of India.—Diener has published in *Palæontologia Indica* (n.s., vol. v, No. 1, 1913) a memoir on the Triassic Faunæ [*sic*] of Kashmir found by Middlemiss in 1908 and 1909. This fills up a gap in the Indian series, and provides many additional forms for comparison and study. A full description of the stratigraphy was given by Middlemiss in his memoir on the Silurian-Trias of Kashmir in the Records Geol. Surv. India, vol. xl, 1910.

3. New Zealand.—The geology of the Aroha subdivision of Hauraki, New Zealand, forcibly brings to notice how much detailed work remains yet to be done before we can form definite maps of the country. This is a large quarto by Messrs. J. Henderson and J. A. Bartrum, and forms No. 16 Bull. N.Z. Dept. of Mines, Geol. Surv. Branch, 1913. Dealing with Climate, Flora, Fauna, Population, Industries, and Geography as well as Rainfall, this memoir though called geological is quite comprehensive in its view. Previous literature is carefully listed and the views of previous writers properly attended to, and the authors throw the whole of the sedimentary rocks into Jura-Trias with the exception of the various 'Recent Deposits'. The large series of Andesites, Dacites, and Rhyolites are described, and much attention is naturally paid to the mining portion of the area. A chapter on Economics closes the Bulletin, which is accompanied with several clearly printed geological maps.

4. Florida and other Coral-reef Tracts.—Dr. T. W. Vaughan having worked for some years on the Floridian Plateau and included in his observation the Bahamas, Marquesas, and Tortugas has issued in the Journ. Washington Acad. Sci., vol. iv, 1914, a "Sketch of the Geological History of the Florida Coral-reef Tract and Comparisons with other Coral-reef Areas". He seems to believe that the final subsidence occurred after uplift following the close of the Pliocene, and notes that Pleistocene terraces rise to 600 feet in Cuba and 1,000 feet in Barbadoes. The Pleistocene barrier reef on Key Vaca showed 105 feet by boring.

5. Mud Lumps.—So far as is known the 'mud lumps' of the Mississippi delta are peculiar to that river. The name of 'mud lump' has been applied to large swellings or upheavals of tough bluish-grey clay in the territory within a mile or two of each of the mouths of the Mississippi. Many of these mud lumps rise just offshore and form islands having a surface extent of an acre or more and a height of 5 or 10 feet, but some do not reach the water surface. They rise and subside at irregular rates, some suddenly, and constant vigilance is necessary to keep charts of

these waters properly corrected. Mr. E. W. Shaw has spent some time studying these features, and the result of his work will be found in Professional Paper 85 B, Dept. Interior, United States Geological Survey, 1913. At most this paper professes to be a brief summary, but the author's observation lead him to state "the facts that the mud lumps are by far the thickest bodies of clay found in the Delta and that the clay is overlain and underlain by materials similar to those found elsewhere throughout the lower end of the Delta suggest that they are produced by a squeezing of the soft layers and an accumulation of clay from such layers in places where the pressure is less strong, and that the lumps are not upheaved by any such force as volcanism or by pressure from the accumulation of salt, sulphur, or gas below the surface".

6. New York State.—So many scattered papers have appeared on the geology of parts of New York State that it is a boon to find that William J. Miller has thrown the whole into a comprehensive and readable general account, clearly written and admirably supplied with maps and illustrations. The 130 pages are divided into Introduction, Physiographic Provinces, Structure and Drainage, Pre-Cambric, Palæozoic, Mesozoic and Cainozoic History, Appendix, and Bibliography. It forms Bull. 168 of the New York State Museum, 1913 (1914), and is issued at 40 cents.

7. Saratoga Springs.—In 1912 J. F. Kemp wrote a report on the springs themselves, and now Messrs. Cushing and Ruedemann have issued a memoir on the district. The rocks are Pre-Cambrian, Cambrian, Ordovician, and Pleistocene (Glacial), and a general description with lists of fossils is given. Several plates show that remarkable Cambrian structure known as *Cryptozoon proliferum* first described by James Hall. The relation of the geology of the area to Burgoyne's campaign forms an interesting, if unusual, chapter in a geological memoir.

REPORTS AND PROCEEDINGS.

Geological Society of London.

May 13, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President mentioned that, on the proposition of Mr. R. H. Tiddeman, President of the Yorkshire Geological Society, a conference would be held in Leeds next autumn to discuss thoroughly the Glacial phenomena of the North of England.

Mr. John Parkinson exhibited (*a*) a few specimens of the old lacustrine beds from the neighbourhood of Lake Magadi, on the borders of British and German East Africa; and (*b*) specimens of soda and silica from the lake itself. The former consist of unconsolidated ash, fine silts with *Planorbis*, and diatomite. These beds in places are probably over 100 feet thick. With the soda is associated silica, which fringes some fault-scarps and forms narrow ridges in the lake itself.

The following communications were read:—

1. "The Scandinavian Drift of the Durham Coast, and the General Glaciology of South-East Durham." By Charles Taylor Trechmann, B.Sc., F.G.S.

The present communication summarizes observations carried out for some time on the superficial deposits of South-East Durham and the lower Tees Valley. It practically embraces the area represented on the two Geological Survey 1 in. Drift maps, Sheet 103 N.E. (New Series 27) and Sheet 103 S.E. Evidence relating to the pre-Glacial levels and contours of the land in the Permian and Triassic areas has been collected and examined. This supports the conclusion that, immediately prior to the oncoming of glacial conditions. the land stood at not less than 100 feet above its present level.

The fissures and depressions of the Middle and Upper Magnesian Limestones on the eastern side of the Shell Limestone reef have been instrumental in preserving relics of the material brought by the earliest ice-sheet which invaded the district from the North Sea. This material proves to be absolutely devoid of the ordinary glacial erratics of the North of England and Scotland, found in the overlying main Drifts. Several narrow vertical fissures are filled with masses of red sandstone, red, grey, and green marl, peat and masses of peaty wood, and Magnesian Limestone, both of immediately local occurrence and of material strange to the district.

The Scandinavian Drift proper occurs about midway between Hartlepool and Seaham Harbour, and occupies a position near the middle of the stretch of coastline where the red fissures are seen. It has been preserved in a pre-Glacial depression and fissure in the underlying Magnesian Limestone, extending over slightly under a quarter of a mile. It is represented by a transported shelly clay containing a fauna of Arctic affinities, which recalls that of some of the basement clays of Flamborough and Holderness. Among other erratics, a big boulder of titaniferous syenite was found resting immediately upon the Magnesian Limestone near the southern end of this section; special notice was taken also of a very big laurvigite-syenite (5 feet long) and two rather smaller rhomb-porphyries lying on the shore opposite this place.

All the stones (between 300 and 400 specimens) found in this clay were collected and examined. The greater part of them are well-glaciated crystalline rocks, many of which (the typical Christiania eruptives) certainly are, and the greater part may be, of South Norwegian origin. Permian limestone, red sandstone, Chalk, and splintered flints also occur.

The apparent absence of any East Scandinavian rocks in Durham is noticed, and an explanation offered. The early retreat of the Scandinavian ice from the Durham coast, as also its relation to the English and Scottish glaciation, is discussed.

Later than the fissure-filling material are certain water-deposited gravels and sands, which occupy shallow depressions underlying the main Drift seen on the coast. They are noticeable for containing a rather large proportion of gneissic and schistose rocks, olivine-basalts, etc., in this case presumably of Scottish origin. A comparison with a similar bed on the Northumbrian coast, studied by Dr. J. A. Smyth, is made.

The main Drifts of South-East Durham are briefly described, more especially in relation to the limits and direction of flow of that part of the ice-stream which carried Cheviot material in the last phase of the maximum glaciation of the east coast. The direct southerly or south-westerly movement of this ice towards the northern face of the Cleveland Hills at this period is indicated by striæ, by the western limits of Cheviot material in this area and in Northumberland, and by the superficial mingling in the lower Tees Valley of the products of this ice with material brought at an earlier period over Stainmoor.

The occurrence of Shap Granite and olivine-basalt erratics is indicated on an accompanying map.

The conspicuous kaimes developed about the village of Sheraton and others, associated with the Cheviot Drift, are described. A few remarks are added on a deserted watercourse at Ferryhill, and on the question of post-Glacial erosion.

2. "On the Relationship of the Vredefort Granite to the Witwatersrand System." By Frederick Willoughby Penny, B.Sc., F.G.S.

The Vredefort Granite has always been considered as a member of that 'old granite' group, which everywhere in the Transvaal and in the Orange Free State is found emerging from beneath the Witwatersrand Series.

The relationship of this 'old granite' group to the overlying rocks has been the theme of frequent discussion. The Vredefort area was made the subject of a paper in 1903 by Dr. G. A. F. Molengraaff, who proved to his own satisfaction the intrusive nature of the granite into the encircling sediments. In the following year, however, when work in other areas indicated the probability that there the 'old granite' group formed the floor on which the Witwatersrand Beds were laid down, Dr. Molengraaff practically withdrew his previous deductions regarding the Vredefort area.

In the present paper evidence is brought forward to prove clearly the intrusive character of the Vredefort Granite, not only into the Witwatersrand Beds, but also into the basic intrusion associated with them, based on an examination of the adjacent rocks and a detailed map of several miles along its contact on the north-east side of the granitic boss in the Orange Free State. It is shown that along its margin the granite has removed, possibly by absorption, but more probably by 'underhand stoping', varying amounts of the sediments from point to point; that it has reacted with the basic intrusions in the sedimentary beds, with the consequent production of hybrid rocks; that, in one place, a subsidiary intrusion of granite occurs in the middle of the diabase; and, finally, that the granite, where it comes into contact with the slate members of the Witwatersrand Series, has induced a definite type of metamorphism in them, producing a magnetite-actinolite-staurolite rock, which is of an entirely distinct type from that induced by the basic intrusion associated with the Witwatersrand Beds, a micaceous phyllitic rock. It is suggested that the Vredefort Granite, instead of being 'Archæan', is of a post-Pretoria–pre-Karroo age, if not contemporaneous with, at least connected with, the same epoch of igneous activity as the 'Red Granite' of the Northern Transvaal.

May 27, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read :—

1. "On the Development of *Tragophylloceras loscombi* (Sow.)." By Leonard Frank Spath, B.Sc., F.G.S.

During his investigation of the Charmouth Lias Mr. W. D. Lang has carefully collected abundant fossil material with reference to its exact stratigraphical horizon, and the author is indebted to him for permission to study the Ammonites. In the material, *Tragophylloceras loscombi* (Sow.) is represented by hundreds of specimens (chiefly young), and a study of the ontogeny of this interesting Ammonite forms the basis of the paper.

A considerable number of specimens were dissected back to the initial chamber or protoconch, and their development was traced in detail. Horizon and history (notably previous interpretations and generic vicissitudes) are also discussed, tables of measurements are given, and the other species of the genus [especially the pre-*ibex* *Tragophylloceras numismale* (Quenst.), which had long been confused with the post-*ibex Tr. loscombi* (Sow.)] are reviewed.

The evolution of the suture-line was worked out in great detail, and one of the most important points brought out was the demonstration of a simple *Psiloceras*-like suture-line persisting to a late and post-constricted stage. The speculations regarding the bearing of all the important facts upon the phylogeny of the genus *Tragophylloceras*, and upon the connexion of the latter with allied lineages, will prove, it is hoped, of general interest. The development of the suture-line in *Psiloceras* and *Rhacophyllites* is given for comparison.

Since *Tragophylloceras* has morphic equivalents in *Rhacophyllites*, as well as in *Analytoceras*, but, by its suture, is more nearly related to *Euphyllites* and the Psiloceratidæ, it is argued that it can more naturally be attached to those *Mojsvarites* descendants that Professor Diener would group in the Pleuracanthitidæ rather than to the typical Phylloceratinæ.

The pre-Triassic ancestors of the Monophyllitinæ are also reviewed, and a new classification of the family Phylloceratidæ is proposed.

2. "The Sequence of Lavas at the North Head, Otago Harbour, Dunedin (New Zealand)." By Professor Patrick Marshall, M.A., D.Sc., F.G.S.

The North Head of Otago Harbour is situated 13 miles north-east of Dunedin, and forms a more or less precipitous cliff ranging from 300 to 530 feet in height. This cliff presents a remarkably clear section of a succession of lava-flows, including trachyte, trachytoid phonolites, kaiwekites, trachydolerites, and basalts. It appears that all the lavas were erupted from the same vent, although the surface features do not indicate the point from which they were extruded. Each sheet is covered by a bed of scoria, the general coarseness of which proves that the centre of volcanic activity was not far distant. The author gives a detailed account of the succession of twenty-five flows and the field relations, which leaves no doubt as to the order of extrusion; but the main portion of the paper deals with the petrography of the lavas. The lowest lava is a trachyte composed entirely of anorthoclase-felspar, and is succeeded by a phonolite in which sanidine is the most conspicuous mineral. This is followed by a series of ten basalts of moderately basic character. The next flow is a kaiwekite, a lava of entirely different type, in which a hornblende allied to barkevikite forms the largest crystals. It also contains titaniferous augite bordered with ægirine, and phenocrysts of labradorite and anorthoclase. The lava above contains no phenocrysts, the pyroxene is ægirine, the hornblende is ænigmatite, and there is an abundance of nepheline. Then follows a series of basalts, including two flows of trachydolerite. The lower trachydolerite contains large phenocrysts of nepheline and sodalite, with only a little felspar in the ground-mass. The basalts are succeeded by a phonolite which contains a few phenocrysts of anorthoclase.

The author then discusses the chemical composition and classification of the lavas. He points out that in the lowest trachyte lime and magnesia are practically absent, but that the second lava (phonolite), although still deficient in these constituents, shows a distinct advance. The basalts as a whole are low in magnesia and above the average in alkalies. In the kaiwekite the alkalies advance very considerably, and there is a corresponding increase in silica and decrease in lime and magnesia, features which are still more marked in the succeeding phonolite. He regards the kaiwekite as a connecting link between the basalts below and the phonolite above. The higher basalts are in general somewhat richer in alumina and poorer in lime than those which occur lower in the section.

The lower trachydolerite compares chemically with the kaiwekite, but the presence of nepheline makes it somewhat richer in soda and alumina, and relatively poorer in silica. The final phonolite compares closely with that near the bottom of the section, but is less alkaline than that near the middle of the series.

The majority of the rocks fall into well-known and readily recognized groups. The lowest lava is a trachyte which may be regarded as the effusive representative of a bostonite. The lowest and highest phonolites, being poor in nepheline, are of the trachytoid type, but the central phonolite is almost a nephelinite in character. The basalts are more or less of the normal type and call for no special comment, but the affinities of the kaiwekite and the trachydolerites are discussed in some detail.

The author considers that the porphyritic rocks of intermediate composition, such as the kaiwekites and trachydolerites, may have formed from an undifferentiated magma, a consideration that requires a threefold eruption from a deep source to an intermediate level. In this case, after a partial eruption of the magma at this intermediate level, complete resorption of the barkevikite and some other minerals would take place, and the residue would differentiate under the forces of gravity into two portions. An upper portion would give rise to the dense non-porphyritic phonolites, and the lower portion would provide the basalts.

The chemical composition of the intermediate lavas, as well as their mineral composition, would suggest that the original magma was that of essexite. It is important to note that in the Island of Tahiti, where there is a similar assemblage of alkaline and basic lavas, the reservoir has been laid bare by denudation and contains essexite as the dominant rock.

OBITUARY.

Dr. ALFRED ERNEST BARLOW,

M.A., D.Sc., F.R.S.Can., F.G.S.A., etc.

Born 1861. Died May 29, 1914.

Amongst the terrible loss of life in the St. Lawrence disaster by the sinking of the *Empress of Ireland*, there comes as a shock to all geologists and mining men interested in the occurrence of ore-deposits in the Archæan crystalline rocks of Canada the loss of one who, for the past thirty years, has taken a most active part in the deciphering of the structure of the earth's crust in the great crystalline areas of North America.

In Dr. Barlow Canada had the last court of appeal on the genesis of its ore-deposits. Trained first at home in Montreal by his father, Robert Barlow, geologist and cartographer under Sir William Logan, of the Geological Survey of Canada, Barlow studied at McGill University under Sir William Dawson, Dr. Harrington, and other geologists, and was asked to join the technical staff of the Geological Survey of Canada in 1883, at Ottawa, under Dr. A. R. C. Selwyn. Filled with energy and enthusiasm for the science of geology, he entered the field in the province of Quebec, and later on wrought hard in the nickel and copper-bearing deposits of the Sudbury region in Ontario. His work in the area under question is a monograph of the greatest value, and his reports and papers regarding the genesis of the nickeliferous pyrrhotite of the region, and the occurrence of the same in the various types of crystalline rocks developed during the magmatic differentiation which took place are recognized as the best and most natural and practical treatises. In the Cobalt silver-mining district of Ontario, throughout the Lake Temiskaming areas of crystalline rocks, in the iron-ore region of Lake Timagami, as well as in the gold-bearing rocks of the Porcupine District, on the Montreal River, and in the Haliburton and Bancroft region of Southern Ontario, throughout the Hastings Series, besides the special district of Dungannon (where corundum deposits are found), Dr. Barlow was *the* worker who, with unceasing energy and devotion to the solution of the difficult problems presented in these various fields, characterizing nearly as many petrographical provinces, has left a record of noteworthy achievement to our science. His writings are numerous and important. Fearless in all his endeavours to ascertain the truth, he published the same, as it presented itself to him, in an equally fearless fashion. Of a vigorous temperament and endowed with unbounded activity and intellectual strength, Dr. Barlow found a wide field for his geological investigations, and his reports breathe that spirit of originality, of thought, and of personal care and attention, of minute petrographical and microscopical details, which were necessary in the study of the many areas of ore-deposits entrusted to him by the various directors of the Geological Survey under whom he wrought for the past twenty-five years. It was under Dr. Selwyn and Dr. Dawson, as well as under Dr. Low, that he was enabled to do his best work. In mining centres he was the welcome geologist and friend to be consulted, and his information both in the field and in the office was the final word that gave satisfaction to the various inquiries made covering the areas above mentioned. His loss is great, and his work was thoroughly good during the brief half-century of his existence. At the March (1914) meeting of the Canadian Mining Institute held in Montreal he was the retiring President, and he did much for the Institute and the mining fraternity to bring about close relations between the thoroughgoing geologist and the practical mining engineer, a relation of the greatest value in any community where the mineral resources of a country are of such vast import as in Canada, realizing as they do now an annual value of some 135,000,000 dollars. During the Twelfth International Congress of Geology held in Canada last year Barlow was a host in himself. In him Canada has lost a diligent and successful as well as honest and fearless geologist, whose convictions went before his personal advantages or aggrandisement in an unselfish aim to bring his chosen science and its value to the State to the forefront in an unblemished career.

H. M. Ami.

Seaford, Sussex.

NEWTON HORACE WINCHELL.

Born December 17, 1839. Died May 2, 1914.

Professor Newton Horace Winchell died on Saturday, May 2, in a hospital at Minneapolis (the city in which he lived). He was in active health and work up to a few days before his death (which resulted from a surgical operation). Professor Winchell was born in N.E. New York on December 17, 1839, and died in his 75th year. His great work was as State Geologist of Minnesota, for twenty-eight years (1872–1900). He was Founder and Editor of the *American Geologist*, which was published for eighteen years in Minneapolis (1888–1905). Since 1906 Professor Winchell was in charge of the Department of Archæology of the Minnesota Historical Society.

Minnesota Historical Society.
May 18, 1914.

Warren Upham,
Secretary and Librarian.

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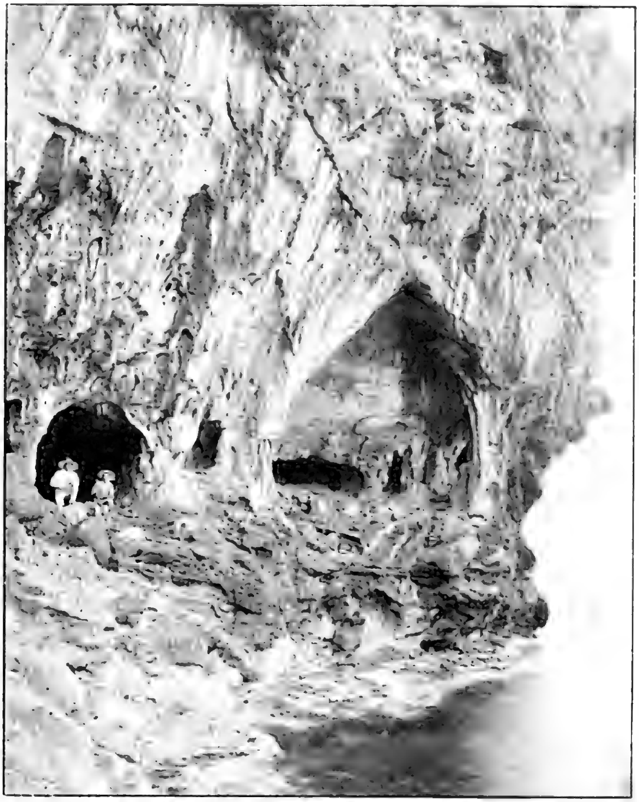

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Fig. 1.—Lower chambers of Cuevas de los Colombs, Cap Faruch, Mallorca.
Fig. 2.—Site of part of fissure deposit, Torre Vieja, Menorca.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. I.

No. VIII.—AUGUST, 1914.

ORIGINAL ARTICLES.

I.—On the Pleistocene Ossiferous Deposits of the Balearic Islands.

By Dorothea M. A. Bate.

(PLATE XXV.)

I. Mallorca.

LIKE so many of the islands of the Mediterranean the Balearic group has yielded interesting remains of an extinct Pleistocene fauna. These have been discovered in cave breccias and in fissures of which a brief description may be of interest.

Previous to 1909 the only record of the occurrence of any Pleistocene mammalian remains in the Balearic Islands was, I believe, that of De la Marmora,[1] who mentioned indications of a bone breccia in the hill of Belver, near Palma, where he observed a bone which appeared to be that of a *Lagomys* or a rabbit. Since then, as the result of three short visits undertaken by the writer, a quantity of ossiferous remains have been obtained from the caves and fissures of Mallorca and Menorca. It may be mentioned that I failed to locate the breccia recorded near Belver.

Mallorca (Text-fig. 1) is the largest island of the group, in shape an oblique square, or trapezoid, containing an area of 430 square miles. Its geological formation has been exhaustively studied by Hermite [2] and others, and it will only be necessary here to state briefly that it is almost entirely composed of Jurassic and Miocene Limestones. The extent of either is very noticeably defined in the general appearance and elevation of the country, the former being invariably the more rugged and mountainous. Palma, the capital and largest coast town, lies on the edge of a strip of diluvial soil which stretches across the island to the marsh lands of the Albufera on the Bay of Alcudia in the north-east. Other formations, including some of Lower Eocene age, but of still smaller extent are also to be seen, but have no immediate bearing on the subject in hand.

The Jurassic Limestone occurs in two isolated masses. The larger of these forms the chief mountain chain, which runs in a north-easterly direction from the Islet of Dragonera to Cabo Formenton; the distance between these two points represents the greatest width of the island. This range rises to a height of 1,445 metres and exercises a most beneficial influence on the climate of the fertile

[1] "Observations géologiques sur les deux Iles Baleares": Mem. Accad. Sci., Torino, sér. I, vol. xxxvii, p. 59, 1855.

[2] *Etudes géologiques sur les Iles Baléares*, Paris, 1879.

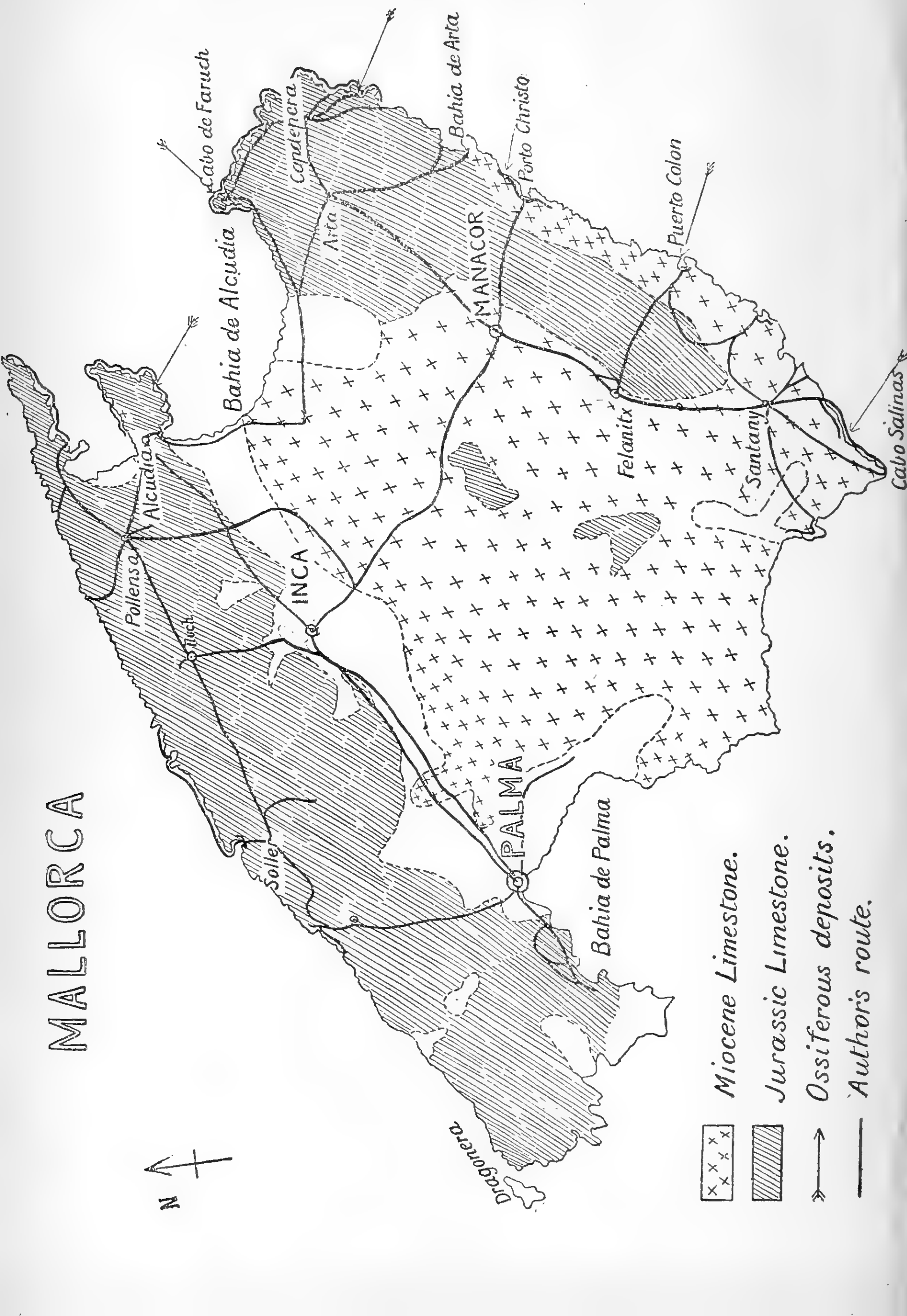


FIG. 1. Sketch-map of Mallorca.

plains, which, by its means, are protected from the winds that sweep almost continuously across the adjacent island of Menorca. The smaller of the two Jurassic masses occupies the eastern corner of the island from the Bay of Alcudia to the Bay of Arta, where this formation leaves the coast and continues as a narrow strip to a little beyond the village of Concos. A few small outcrops of this rock are also met with in the central plain. This central portion of the island is composed of a Miocene Limestone which extends to the southernmost point, Cabo Salinas, from which it forms the coast-line for a considerable distance in either direction.

Numberless caves occur in each of the above-mentioned limestone formations, and Mallorca is justly celebrated for its wonderful caverns, which often extend over very large areas. Many have been exhaustively explored by M. E. A. Martel, who has published interesting accounts of his investigations in Spelunca. It will suffice here to mention that the most important and best known are those of Arta and the Drach, both situated on the coast and in the Jurassic and Miocene Limestones respectively. The latter contains a considerable amount of fresh water, and in 1904 the researches of M. Racovitza were rewarded by the discovery of an aquatic blind Isopod ascribed to a new genus[1] as well as other representatives of an interesting fauna. Other grottoes of considerable size are those of Pirata, one at Orient in the northern range, one discovered recently near Cabo de Menorca, and doubtless many unknown to more than local fame. Most of the above and many other large caves were visited, but in none were indications of an ossiferous deposit discovered.

Six Pleistocene ossiferous deposits were discovered in Mallorca, of which the following is a list:—

1. Near Porto Christo.
2. Cave at harbour mouth of Puerto Colon.
3. Cala Figuereta, near Santañy.
4. Cave, Fuente de la Cala, near Capdepera.
5. Cuevas de los Colombs, Cap Faruch.
6. Cave near Cabo de Menorca, Alcudia.

The first three were situated in sea cliffs of much worn Miocene Limestone and were very fragmentary, yielding no specimens worth preserving. No. 3 was represented by but a single limb-bone, probably that of *Myotragus*, attached to the rocks only just out of the water in calm weather. No. 1 is at the summit of the cliffs a few yards from their edge; what is left of the bone breccia lies between layers of stalagmite and measured 6 by 2 or 3 feet. An isolated bone a few yards distant indicated the originally greater extent of the deposit. Its appearance suggests that it was formed in a fissure, but in this connexion it may be worth recording that near the cliff edge for a distance of about half a mile from this spot there are innumerable traces of the bases of stalagmites and of stalagmitic layers. These may extend uninterruptedly for a hundred yards or more, and suggest the former existence of a system of caverns and galleries of vast extent.

[1] Bull. Soc. Zool. France, tom. xxx, No. 4, p. 72 et seq., Juillet, 1905.

The three ossiferous deposits given last in the above list were contained in coast caves in the Jurassic Limestone. Owing to this protection these were more extensive and better preserved than those described above.

No. 4 is locally known as the Cueva de la Barxa. An entrance is effected through a rent in the roof, and a drop of 7 or 8 feet gives access to a chamber about 20 yards long by 5 wide; both roof and rock-strewn floor slope down to what was the original entrance and where the sea now breaks through and ordinarily fills perhaps half the floor space with quiet pools. At the inner and upper end a small opening leads to the main portion of the cavern. This contains stalactites and a stalagmitic flooring partially covered with fresh water and with a few Recent bones already attached to its surface by a coating of lime deposit.

The mammalian remains were obtained from the chamber first entered. Here the whole floor had formerly been covered by an ossiferous deposit 6½ feet thick. This had been subsequently almost entirely demolished, leaving small isolated patches of bone breccia in crevices in the walls. The full force of the waves can have barely reached the extreme length of this chamber, for a small part of the ossiferous flooring remained at its inner end immediately below the opening leading to the larger cavern. A section of this was exposed, showing it to be at this point about 3½ feet wide by 3 deep. It rested on stalagmite, and its upper surface was also protected by an uneven crust with a minimum thickness of 4 inches, which was greatly exceeded in places. The face of the section was also partially covered by stalagmite an inch thick, which must have formed subsequently to the general destruction of the flooring. The most important remains obtained here were those of *Myotragus balearicus*, including the type-specimens.[1] Numerous land shells also occurred, some with traces of colour still persisting. These were kindly identified by the late Rev. R. Ashington Bullen[2] as *Vitrea lentiformis*, *Otala balearica*, *Helicella myelli*, and *Tudorella ferruginea*, species still extant in the islands.

The promontory forming the northern shore of the Bay of Alcudia is composed of Jurassic Limestone. In the cliffs near Cabo de Menorca, and about 25 feet above the sea, were two cleft-like grottoes which might formerly have been neighbouring chambers of one large cavern. The eastern half, No. 6 of the list, was only 3 feet high by 10 or 12 wide at its entrance; the floor was of rough, uneven rock, and there were a few traces of ossiferous remains. The most important of these was to one side, where a section was exposed of a deposit of reddish earth two yards in extent and surmounted by two thin layers of stalagmite. The specimens contained in this earth were thickly coated by a limey concretion, which also massed

[1] "A new Artiodactyle from Majorca, *Myotragus Balearicus*, gen. et sp. nov.," by D. M. A. Bate: GEOL. MAG., 1909, pp. 385–8. See also Reports and Proceedings, Royal Society, June 18, 1914, "Description of the Skull and Skeleton of a Rupicaprine Antelope, *Myotragus balearicus* (Bate)," by Dr. C. W. Andrews, F.R.S.: GEOL. MAG., reprinted *infra*, p. 378.

[2] Proc. Malac. Soc., vol. ix, pt. ii, June, 1910, pp. 118–22.

a number together. This condition of the bones in a soft matrix pointed to their not being in their original place of deposition.

In the extreme east of Mallorca lies a considerable tract of uninhabited and mountainous country. It is composed of a Jurassic Limestone and culminates in Cabo de Faruch, which forms the eastern horn of the Bay of Alcudia. A little to the south-east of this a rocky point jutting into the sea has its face pierced by about six or seven grottoes and cavities known as Cuevas de los Colombs, No. 5 of the list. The lowest of these, shown in Pl. XXV, Fig. 1, was not more than 15 feet above the sea, and the series of openings continued in a steeply ascending line for a distance of 50 or 80 yards. The floors of the uppermost ones were covered with dry sand, but it was only in the lower that any ossiferous remains were observed. It can be seen from the accompanying photograph that the cliff face had evidently broken away, leaving the caves exposed to the action of the waves. In winter these break in with great violence and have effectually destroyed the stalagmitic and ossiferous flooring formerly present. Fragments of this were found only in holes and crevices protected from the full force of the breakers.

The highest point at which mammalian remains occurred was in the only portion left of the main cave floor deposit. A section showed this to consist of a layer of earth and some bones 4 to 5 feet thick surmounted by one of red earth a foot or more in depth; its surface was protected by 4 to 6 inches of stalagmitic crust. Almost all the remains obtained were procured from two 'pockets' in the inner wall of one of the chambers. The openings to these were small and insignificant and gave no indication of the enclosed deposits. On the entrance to one being enlarged, it was found to run in for a distance of slightly over 6 feet, and was filled almost to its roof by a deposit of mammalian remains in a wet red earth covered by stalagmite $\frac{3}{4}$ of an inch thick. The second 'pocket' was entirely filled with a very similar deposit, though here bones of birds and rodents were more plentiful, especially in the upper part of the cavity. The remains were chiefly those of *Myotragus*; many scattered fragments of pine charcoal[1] occurred and several pharynges of the wrasse with their rows of teeth were also obtained.

Two days were spent on the small island of Cabrera off the south coast of Mallorca, where several caves were visited, but no ossiferous remains were encountered.

II. Menorca.

A third visit to the Balearic Islands was made possible in the autumn of 1911 by the receipt of a grant from the Trustees of the Percy Sladen Memorial Fund. On this occasion the primary object was to search for Pleistocene mammalian deposits in the smaller islands of Menorca and Ibiza, from which no ossiferous remains had been previously reported.

Ten days were first spent in Ibiza, which is a hilly island with a greatest length of 41 and a breadth of 20 kilometres. Many caves were visited, but no trace of any ossiferous deposit was discovered here.

[1] These were kindly examined and identified for me by Miss E. Loraine Smith.

Menorca (Text-fig. 2) is the most easterly of the group and lies 27 miles from Mallorca, from which it differs greatly in many important respects. It has an extreme length of 49 kilometres with a greatest width of 21 kilometres. The coastline is said to measure over 200 kilometres. An imaginary line may be drawn from a point on the coast some miles to the north-east of Cabo Bajoli throughout the length of the island to Mahon in the south-east. To the north and east of this lies a low, broken country of divers formations in isolated strips. These include several outcrops of Jurassic Limestone, one of which forms the highest point of the island, Monte Toro, which attains a height of a little over 1,100 feet. To the west and south of this imaginary line the island is entirely composed of Miocene Limestone. This forms a flat-topped plateau

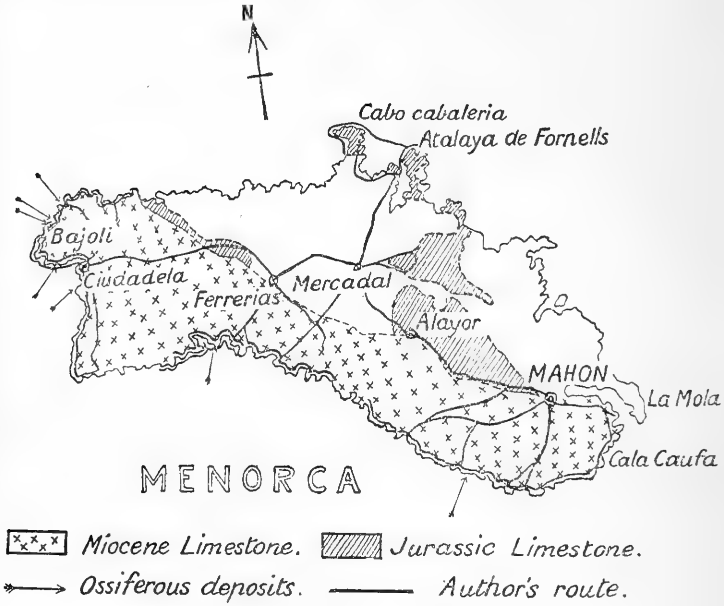


FIG. 2. Sketch-map of Menorca.

averaging about 200 feet in height. Especially at no great distance from its coastal edge this country is cut by innumerable barrancos, which are almost all narrow and range from a few hundred yards to several miles in length; many have precipitous sides, which may attain as much as 200 feet in height.

Seven ossiferous deposits were discovered, all within the Miocene Limestone area and all close to the sea. The following is a list of the localities:—

1. Fissure, Torre Vieja, Bajoli.
2. Small fissure, Sestrucarias, Bajoli.
3. Fissure, Sestrucarias, Bajoli.
4. Ossiferous deposit near Ciudadela Lighthouse.
5. Ossiferous deposit in cliffs south of Ciudadela.
6. Cave near Santa Galdana Barranco.
7. Ossiferous deposit near Cala de Binidali.

Besides the above, some fragmentary remains consisting of a few land shells and a small piece of bone embedded in the typical red matrix were found in a coast cave east of the mouth of the Santa Galdana Barranco. These no doubt indicated the former existence of an ossiferous deposit.

Two of the deposits, Nos. 4 and 5 in the list, were situated in low cliffs and were but a few feet above the sea. So little remained of either that their former condition could only be surmised as that of cave-deposits. The few bones left appeared to be those of *Myotragus*.

In only one instance (No. 6) were ossiferous remains found actually in a cavern. This was in the Cueva de los Extranjeros, so called from the neighbourhood of some deserted barracks, a relic of the British occupation; this cavern is situated in the cliffs between the mouth of the Santa Galdana Barranco and the small bay of Marcaria. It faces the sea, from which it is only separated by a few yards of sloping rock. Most of the single chamber was roofed and ran in for a distance of about 84 feet, the width being 15 to 20 feet and the height 25 to 30 feet.

At the entrance the floor was heaped with irregular blocks of stone, doubtless the result of incursions by the sea. The inner 18 feet were covered by a sloping sandy deposit, which, at one point, rose to within 8 feet of the roof. Its face had fallen away, leaving a section exposed, and this showed that the uppermost layer, 1 to 2 feet thick, contained a quantity of mammalian (*Myotragus*) remains accompanied by land shells. The entire deposit, including the ossiferous band, had evidently been introduced into this chamber by means of water which had found a way through a channel in the rock. The opening of this was found at the apex of the cave; it was choked with stalagmite, and a number of bones were also present here. The originally much greater extent of the cave breccia was indicated by the presence of land shells enclosed in red matrix at a considerable distance from the present deposit. Similar indications were observed in a second and larger cavern lying a little to the east of the one just described.

Three ossiferous deposits which had undoubtedly been accumulated in fissures in the limestone rock were found near the coast of the Bajoli district, north of Ciudadela. The cliffs in places rise to a considerable height, 200 feet and more, and this promontory, like a great part of the Miocene coastline, is edged by a barren strip of the much-weathered limestone. Here and there this was covered by long strips or sheets of stalagmite with occasional bases of stalagmitic columns.

One of the deposits (No. 2) was in a small crevice on the cliff face and near its summit. The red matrix contained a mass of small remains, including those of a dormouse, two shrews, etc. The two other fissure deposits were situated on the neighbouring farms of Sestrucarias and Torre Vieja, and were very similar; both lay parallel to the edge of the cliffs at a distance of perhaps a hundred yards and within the barren border mentioned above. Likewise both were intersected by a narrow gully leading to the sea. In each case there remained but the merest remnant of the original deposit, which barely retained anywhere a thickness of a foot, and in many places only sufficient matrix was present to contain a thin section of bone.

The Sestrucarias deposit was perhaps the more weathered of the two. Traces of it 2 yards in width could be seen to the left of the gully for a distance of about 20 yards. Similar pieces of red matrix and bones occurred at the bottom of the ravine and again for another 60 yards beyond. The second of these deposits (Pl. XXV, Fig. 2) was found in and around a slightly larger ravine terminating in an opening to the sea known as the Cala de Pous. The ossiferous remains were observed in the bed of the barranco, in the rocks forming its steep sides, and also beyond its limits. Though difficult to estimate correctly the original size of the deposit, it could be traced for 20 feet or more from either edge of the barranco and had a width of at least 40 feet and a depth of 10 to 12 feet.

The remains were almost all those of a gigantic land tortoise[1]; a few bones and teeth of *Myotragus* were obtained at the top of the smaller deposit and some rodent and bird bones occurred in the larger one. Some fine sections were made from the limestone and the red matrix of these deposits, and were kindly examined by Mr. R. Bullen Newton, who found them to be almost entirely composed of remains of *Amphistegina* accompanied by the marine Alga, *Lithothamnium*. The former had not previously been recorded from this locality.

One more ossiferous deposit discovered in Menorca was situated within a few yards of the edge of the sea cliffs near the little Bay of Binidali on the coast between the villages of San Clementi and San Luis. It had probably been formed in a fissure, and, though smaller and very fragmentary, was not unlike those of the Bajoli promontory described above. The mammalian remains were scattered in rather isolated patches over an area about 8 or 10 yards long by 2 yards broad. The depth of the deposit nowhere exceeded 2 feet. A block of limestone lying a short distance away also showed traces of remains. *Myotragus* remains occurred here, but those of rodents and other small forms were still more plentiful.

III. Conclusion.

Some of the most interesting points with regard to the Pleistocene ossiferous deposits of the Balearics may be briefly summarised as follows:—

1. Every one of the deposits discovered both in Mallorca and Menorca was situated in close proximity to the sea.
2. All were largely, some almost entirely, destroyed.
3. Usually each deposit was composed almost entirely of the remains of a single species.
4. With the exception of some avian, small reptilian, and Molluscan remains, none were obtained of species found inhabiting the islands at the present day.
5. Remains of *Myotragus* occurred in deposits of both islands.
6. Large *Testudo* remains were found only in Menorca, while different, though closely allied, species of 'dormice' were obtained from Mallorca and Menorca respectively.

[1] *Testudo gymnesicus*, Geol. Mag., March, 1914, pp. 100–7.

Almost all ossiferous cave-deposits are formed in either one of two ways :—

1. The caves have been the haunt of predatory animals or man, who not only left their own remains in the cavern, but also those of the animals brought in as the spoils of the chase.

2. Or the remains have been introduced and accumulated through the agency of water.

I believe that all the Balearic cave-deposits have been accumulated in the latter manner, and, further, that all are now approached by their original terminal end.[1] This would help to account for all having been found on the coast, for here the action of the sea and in some cases alteration of the coast-level have aided and accelerated weathering. Thus cliff faces may be worn and broken away, leaving exposed underground channels and chambers with their accumulated contents. A continuation of this same work of destruction added to rapid weathering is sufficient to account for the very generally fragmentary state of the deposits. This last might partially explain the paucity of species. The remains may have been introduced into the caves as either skeletons or carcases, and it is the latter, no doubt, which account for the finding of associated skulls and mandibles and other bones. Similar conditions to the above have been observed by the writer in many Pleistocene cave-deposits of other islands of the Mediterranean.

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

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

(*Continued from the March Number, p. 99.*)

(PLATE XXVI.)

THE group of *Membraniporæ*, with a small median barred avicularium placed immediately above the oœcium, of which *M. Griffithi*, Bryd., is a leading instance, contains several Senonian members in addition to the Trimingham forms (*M. Triminghamensis*, *M. anterides*, *M. humiliata*) which I have already described in this Magazine. They seem to arise first in the zone of *Micraster cor-anguinum*.

Membranipora simulacrum, sp. nov. (Pl. XXVI, Figs. 1, 2.)

Zoarium unilaminate, always adherent.

Zoœcia large, very slightly subpyriform, areas oval, with average length ·5 to ·55 mm. and breadth ·3 mm.; side walls bent slightly inwards, and so low and slender that at a hasty inspection they might be taken to be mere ghosts of some species with a low arched front wall.

Oœcia very generally present in mature zoœcia, and of circular ground plan; I have not met with a perfect specimen.

Avicularia of two kinds: (1) The characteristic accessory type: these are shuttle-shaped with rounded ends, and have an aperture of

[1] See the present writer's Notes in *Camping in Crete* (A. Trevor-Battye), p. 245, London, 1913.

similar shape but tending towards pointed ends and spanned by a crossbar dividing it into two nearly equal compartments, the upper being slightly the larger: this seems to separate the species from the *M. Griffithi* line and ally it to *M. Trimminghamensis.* (2) Large vicarious inflated forms of the hourglass type with the external front wall much exaggerated and a very delicate areal rim, sometimes initiating new rows of zoœcia, but sometimes occurring in an established row: these are rare and delicate and occur very capriciously.

I have only found this species in the *cor-anguinum* zone of Kent and Hants, in which it occurs sparingly but well distributed, and once in the *Uintacrinus* band of Hants.

MEMBRANIPORA SUFFRAGISTA, sp. nov. (Pl. XXVI, Figs. 3, 4.)

Zoarium unilaminate, always adherent.

Zoœcia rather small, distinctly subpyriform, with oval areas of average length ·38 mm. and breadth ·2 to ·25 mm.; side walls wide, bearing a number of stout spine bases with depressions in their upper surfaces but not apparently perforated, and tending to overlap slightly the outer edge of the side wall; these spine bases are most prominent in the upper part of the zoœcia, but appear to occur all round the area, and the spines must have presented a very militant aspect.

Oœcia small, very globular, slightly bottle-necked, very regularly present after the earliest stages, but delicate and not often preserved, the specimen shown by Fig. 4 being exceptional.

Avicularia accessory, strongly triangular and mandibular, with the beak often produced to a great length in the later stages; a transverse bar divides the triangular aperture into very unequal compartments; no vicarious avicularia.

This species might by its spines be ancestral to *M. Trimminghamensis*, but by its avicularia it is probably ancestral to *M. Griffithi*. It occurs not infrequently in the *cor-anguinum* zone of Kent and Hants and rarely in the *Uintacrinus* band and *Marsupites* zone of Hants.

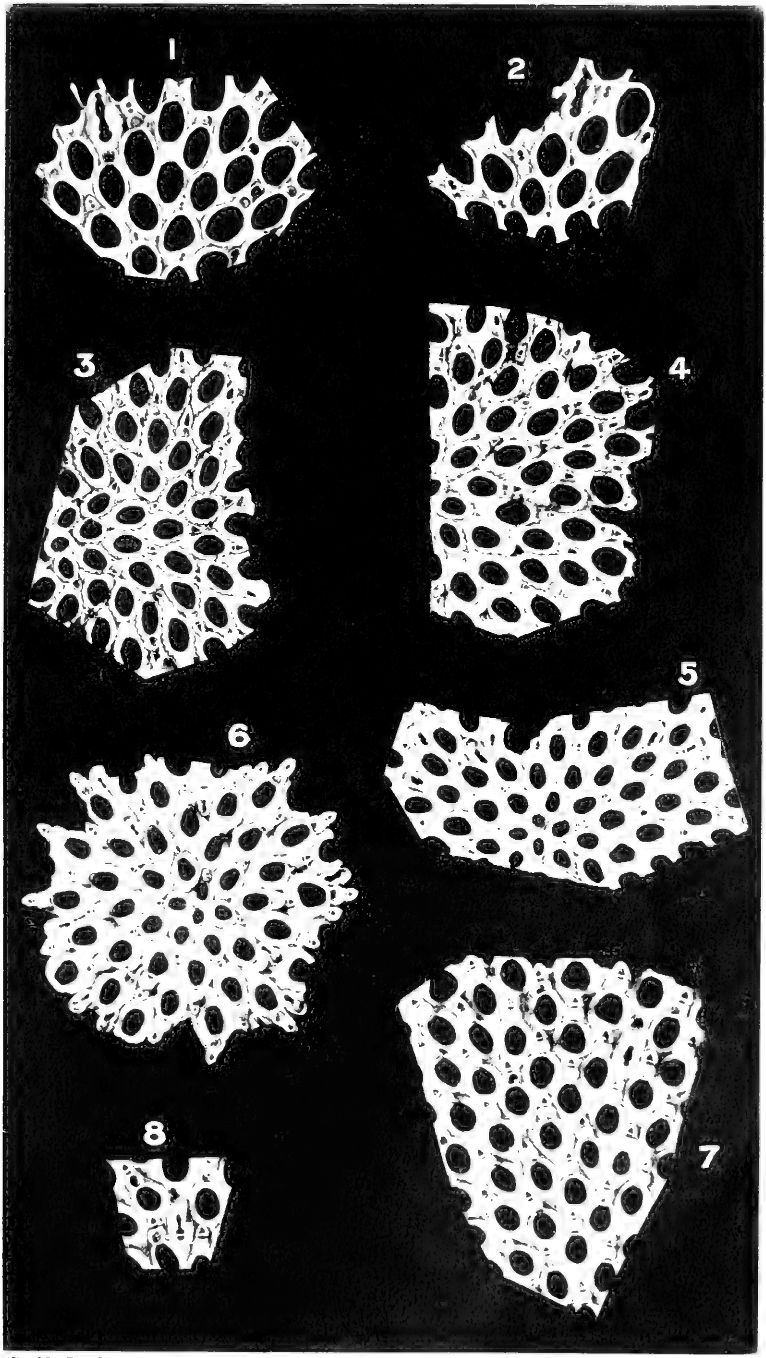
MEMBRANIPORA BOLETIFORMIS, sp. nov. (Pl. XXVI, Figs. 5, 6.)

Zoarium unilaminate, always adherent.

Zoœcia small, slightly subpyriform; areas strongly oval and usually with a flattened and straight upper end, average length ·28 to ·33 mm. and breadth ·18 to ·2 mm.; side walls typically thin, especially at the upper end; in those zoœcia, almost exclusively the very early ones, which have no oœcium there may be observed under high magnification a pair of projecting tubules on the side wall at the extreme upper end, and in most zoœcia traces of one or even two pairs of pores can be seen in the side walls a little lower down, but these features require a much higher magnification than twelve diameters for making them apparent, and I think they are only relics of discarded appendages.

Oœcia almost invariably present after the earliest stages, relatively rather large, globular, and slightly bottle-necked, rarely preserved, the specimen shown by Fig. 6 being most exceptional.

Avicularia of two kinds: (1) The characteristic accessory type, always present, bluntly triangular, with a slightly rounded lower end,



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

Chalk Polyzoa.

the aperture divided by the crossbar into distinctly unequal compartments, but not definitely mandibular. (2) Vicarious, occurring chiefly at the beginning of a new row of zoœcia, but sometimes also in an already established row; they are of the hourglass type with the expanded upper part of the area almost circular, but the lower part narrow and with nearly upright side walls, giving a general outline resembling that of a puff-ball; the transverse bar (which was probably always present in the hourglass type) is placed close to the lower end of the area.

This species occurs in, and seems to monopolize as far as its group is concerned, the zones of *O. pilula* and *A. quadratus* in Hants and Sussex. It is clearly ancestral to *M. Griffithi.*

MEMBRANIPORA GRIFFITHI, mihi.[1] (Pl. XXVI, Figs. 7, 8.)

I take the opportunity of giving photographic figures of this species to assist comparison and correct in small details the original figure. The side walls show a marked tendency to thin away at the upper end, and just about at the point where this thinning begins traces of a pair of pores can be detected. The zoœcia were wrongly stated to have a common external front wall; they are subpyriform with unusually prominent areal margins. The oœcia are strongly bottle-necked, and appear to be not only cut away round the avicularia but also somewhat cut down to them. I am able to figure what is probably a perfect vicarious avicularium with the transverse bar preserved. The species occurs also in the Weybourne Chalk.

EXPLANATION OF PLATE XXVI.

(All figures × 12 diams.)

FIG. 1.	*Membranipora simulacrum.*	Zone of *M. cor-anguinum.*	Gravesend.
,, 2.	,, ,,	,, ,,	,,
,, 3.	*M. suffragista.*	,, ,,	,,
,, 4.	,,	,, ,,	,,
,, 5.	*M. boletiformis.*	,, *A. quadratus* (restricted), Shawford, Hants.	
,, 6.	,,	,, *A. quadratus* (restricted), Seaford, Sussex. A thick-walled variety.	
,, 7.	*M. Griffithi.* Trimingham.		
,, 8.	,, ,,		

III.—ON A FEMUR OF REPTILIAN TYPE FROM THE LOWER CARBONIFEROUS OF SCOTLAND.

By D. M. S. WATSON, M.Sc., Lecturer in Vertebrate Palæontology in University College, London.

(PLATE XXVII.)

WHILST looking over the private collection of fossil fishes made by the late Dr. R. H. Traquair, I found a small tetrapod femur. This bore no label of any kind, but was included in a series of remains of Dipnoi from the Lower Carboniferous of Scotland. The texture

[1] GEOL. MAG., 1906, pp. 289–300, Fig. 1.

of the bone is not unlike that of *Ctenodus*, and was no doubt the reason of its place in the collection.

The very small piece of matrix which is preserved is identical with that of some of the fish from the No. 2 Ironstone, Loanhead, and differs from any other fish-bearing matrix that I know in Britain. [Any one with experience of Carboniferous fishes will recognize that it is usually fairly easy to identify the important localities (the Loanhead ironstones, the various Staffordshire ironstones, etc.) by inspection of the matrix.] Despite the fact that it was not localized, I think that the probability of its being from the Loanhead ironstones is sufficient to justify a description.

Mr. Herring's excellent photographs reproduced in Plate XXVII will give a much better idea of the bone than any description. The head shows a large half-moon shaped area for an articular cartilage, and is directly continuous with the small trochanter, which is carried on by a sharply marked ridge down the rather stouter shaft.

There are two rather unusually distinct condyles at the lower end which were also covered by a cartilaginous cap during life. That this little femur is of reptilian type is obvious; it resembles closely that of *Trispondylus* and even those of certain Pelycosaurs. Such Cotylosaurs as *Labidosaurus* only differ in their more pronounced trochanter. The only amphibian femora which at all resemble it are those of *Trematops* and the Lower Carboniferous *Pholidogaster*. Both, however, differ in their much less distinctly divided lower end, but do resemble it sufficiently to suggest that it is not inconceivable that it is really a precociously advanced Stegocephalian.

I showed some time ago that the Carboniferous Embolomerous Stegocephalia (which are known from the Burdiehouse Limestone) resemble the Cotylosaurs, particularly *Seymouria*, much more closely than do any later amphibia, and suggested that the reptiles arose from the Stegocephalian stock at its base. If the bone figured in this paper be really a reptile, and if it really comes from the Loanhead ironstone, it affords strong additional support to this view, for it is nearly as old as the oldest known Stegocephalian bones and much more ancient than any previously known reptile. In any case it is most probable from general experience that the reptiles did arise from the base of the amphibian stem, or all its later members by adopting some specialization have lessened their potentiality, just as the cells of an embryo when once divided into epiblastic and endoblastic layers are no longer individually capable of giving rise to the whole animal.

There is no doubt that this femur represents a new type, and I am glad to have an opportunity of expressing the pleasure that Dr. Traquair's papers have always given me by calling it *Papposaurus Traquairi*, gen. et sp. nov.

EXPLANATION OF PLATE XXVII.

Type femur of *Papposaurus Traquairi*, gen. et sp. nov. ×1. A, dorsal aspect; B, ventral aspects; C, fibial side; D, tibial side; E, proximal end; F, distal end. ? Lower Carboniferous of Scotland.

Femur of *Papposaurus Traquairi*, sp. nov.
Lower Carboniferous, Scotland.

Sedgwick Museum Notes.

IV.—Notes on the genus *Trinucleus*.—Part III.[1]

By F. R. Cowper Reed, Sc.D., F.G.S.

(PLATES XXVIII AND XXIX.)

I. The Glabella.

1. *The Lobation.*

THE characters of the lateral furrows of the glabella and of the pits which occur in the axial furrows of the head-shield have not had sufficient attention paid to them, and a comparative study of their development in various British species reveals some interesting and important features.

It has been commonly assumed that lateral furrows are absent in some species, and at any rate the omission of any notice of their occurrence in certain cases is difficult to understand. Frequently, moreover, it has been stated that only two pairs are present, even in those species in which the presence of any lateral furrows has been recognized. The nature of the so-called stalk or neck of the glabella has been also generally misunderstood. McCoy's[2] division of the genus *Trinucleus* into two genera, *Trinucleus*, sens. restr., and *Tretaspis*, was largely based on the presence or absence of this stalk and of lateral furrows; for he says the furrows at the base of the glabella distinguish *Tretaspis* from *Trinucleus*, the latter being stated to be without lateral furrows, though the presence of the 'eye-line' on the cheek was chosen as the primary distinctive feature of the former. Nicholson and Etheridge,[3] while rejecting *Tretaspis* as a sub-generic division, mention an additional third pair of furrows at the sides of the anterior swollen portion of the glabella in *Trinucleus Bucklandi*, though they do not seem to regard them as segmental furrows.

In the recent new edition (1913) of the Eastman-Zittel *Text-book of Palæontology* the old genus *Trinucleus* is split into three genera, of which two (*Trinucleus*, sens. restr., and *Tretaspis*, McCoy) are said to possess two pairs of lateral furrows on the glabella. Additional confusion is thus introduced into the usage of the terms. In the case of the third genus, *Cryptolithus*, Green, of which *Cr. Goldfussi* (Barr.) is figured as an example, no mention is made of any furrows or pits and none are shown in the figure. Ruedemann,[4] however, recognized three pairs of lateral pits in *Tretaspis reticulatus*, Rued.

The general failure to recognize more than two pairs of segmental furrows or pits on the glabella is undoubtedly due to the comparatively weak development or obsolescence of the first or anterior

[1] Parts I and II were published in 1912 (Geol. Mag., Dec. V, Vol. IX, pp. 346–53, 385–94).
[2] McCoy, Syn. Palæoz. Foss. Woodw. Mus., 1855, pp. 144–7.
[3] Nicholson & Etheridge, Mon. Silur. Foss. Girvan, fasc. ii, pp. 190–7, 1880.
[4] Ruedemann, Bull. 49 New York State Mus., Palæont. Papers 2, 1901, p. 41, pl. iii, figs. 11, 15–20.

pair, and it is only the second and third pairs to which reference is usually made. In all the best-known British species there are three pairs present, though they are in various stages of development or obsolescence, the first pair indenting the sides of the so-called 'frontal lobe', which is therefore not homologous with the true frontal lobe of other genera (e.g. *Cheirurus*) in which the first lateral furrows bound the frontal lobe posteriorly. For this reason the ovoid or sub-hemispherical swollen anterior portion of the glabella in those species of *Trinucleus* with a stalk or neck to the glabella may be termed the pseudo-frontal lobe.

Another character which has been usually neglected in describing the head-shield is the true course and behaviour of the axial furrows. For it is not usually made clear in descriptions of the glabella that the longitudinal depressions or furrows bounding the stalk of the glabella on each side are not the posterior continuations of the axial furrows but different structures of the nature of the longitudinal furrows bounding the median lobe in some species of *Lichas* and *Acidaspis*, and that there is a more or less definite elongate composite lateral lobe between the stalk and the true axial furrows, as in some species of *Ampyx*. The presence of these composite lateral lobes has generally been overlooked, and the stalk has been regarded as representing the whole posterior width of the glabella, in spite of the meso-occipital ring extending further out on each side at its base.

Certain other pits associated with the axial and other cranidial furrows have been insufficiently noticed in the past, and the fact that the segmental furrows are mostly reduced to pits situated at the inner ends of obsolescent or obsolete furrows has led to confusion in the homology of the five or six pits which are frequently present on each side of the glabella.

The reduction of the segmental furrows to mere isolated pits on the surface of the glabella is by no means uncommon in various genera of different orders and families of trilobites (e.g. *Bronteus*, *Bronteopsis*, *Oryctocephalus*, and some species of *Acidaspis*, *Dalmanites*, and *Cybele*), leading to the more or less complete longitudinal fusion of the lateral lobes of the glabella and the formation of composite lateral lobes as sometimes in *Lichas*.

In the genus *Trinucleus* the British species which shows the nature and number of the segmental furrows and the course of the axial furrows better than any other is *Tr. fimbriatus*, Murchison, from the Llandeilo of Builth (Pl. XXVIII, Figs. 1–3). McCoy[1] described and figured this species from Pencerrig, Builth, and showed in his figure the posterior course of the true axial furrows (though not quite correctly), and the presence of the elongated composite lateral lobes on each side of the neck, but he does not comment on this peculiarity, and only mentions the occurrence of two lateral furrows on each side. A study of a large series of specimens from this locality allows of a fuller description of the head-shield of this interesting species. The anterior half of the glabella is swollen and sub-pyriform, forming the pseudo-frontal lobe; the posterior half is depressed rather suddenly behind it. There is a pair of small, short

[1] McCoy, Syn. Palæoz. Foss. Woodw. Mus., 1855, p. 146, pl. i E, fig. 16.

furrows (the first lateral pair) indenting the base of the sides of the pseudo-frontal lobe close to the axial furrows; a weak, narrow depression runs obliquely inwards and backwards from these indentations to the second pair of lateral furrows, which are represented by large isolated pits at the base of the pseudo-frontal lobe; the third pair of pits lie in the same longitudinal axial line as the second pair; a short arched furrow runs back from each of these third pits, ending on each side in a deep but smaller pit in the meso-occipital furrow, so that a fourth pair of pits is here present. The short curved furrows between these third and fourth pairs embrace between them a slightly swollen basal ring, forming the posterior end of the incipient stalk of the glabella. Outside and between the third and fourth pairs of pits, there is usually a small pit of somewhat uncertain significance, but perhaps representing the outer ends of the third lateral furrows, as it seems to lie in the axial furrows. The true meso-occipital ring extends laterally outside the above-mentioned basal ring, thus proving that the true base of the glabella is wider than this ring, and, therefore, than the stalk of the glabella; and we are thus prepared to find portions of the glabella on each side of the stalk, and to look further out for the posterior course of the axial furrows.

The axial furrows are seen to hold at their anterior ends the small pits which have been erroneously[1] considered to be for the insertion of the antennæ,[2] and may therefore be called pseudo-antennary pits. From these pits they curve gently outwards with a slight convergence posteriorly to the first lateral furrows, but behind them they become gradually weaker, though distinctly traceable for fully three-fourths of the way back to the base of the head-shield, separating the suddenly rising cheeks on the outer side from elongated slightly convex areas on the inside extending from the first lateral pits to the meso-occipital ring, but depressed below the level of the median portion of the glabella—the incipient stalk. These areas are the composite lateral lobes, now merely indented on their inner sides by the pit-like second and third lateral furrows, but bounded externally by the axial furrows. The posterior ends of the axial furrows are almost obsolete, but their position is marked on each side by a notch in the posterior margin of the head-shield and by the junction of the meso-occipital and pleuro-occipital rings.

We thus see distinctly that the glabella in this species consists of (1) a pseudo-frontal lobe, (2) a median posterior stalk-like portion, and (3) a pair of elongated composite lateral lobes.

We also note that there are three pairs of segmental furrows, of which the second and third pairs are represented by more or less isolated pits not connected with the axial furrows; and that the third pair is connected with a fourth pair of pits lying in the meso-occipital (but not in the axial) furrows, leading to the formation of a basal transverse swelling or ring.

Finally we note the incipient obsolescence of the true axial furrows behind the first lateral furrows. All these features we find reproduced

[1] Oehlert, Bull. Soc. Géol. France, ser. III, vol. xxiii, p. 302, 1895.
[2] McCoy, Syn. Silur. Foss. Irel., 1846, p. 42.

with modifications in other species, such as *Tr. seticornis*, *Tr. Bucklandi*, *Tr. Murchisoni*, etc.

In the case of *Tr. Murchisoni*, Salter,[1] from the British Arenig rocks (Pl. XXVIII, Figs. 4, 4*a*), the incipient differentiation of the stalk of the glabella is rather less advanced. The glabella as a whole is of an ovoid form with the anterior part more inflated than the posterior, but the pseudo-frontal lobe sinks down more gradually into the stalk, which is not so independently cylindrical as in *Tr. fimbriatus.* The first lateral furrows are very short deep notches arising from the axial furrows and indent the sides of the pseudo-frontal lobe at about half its length, but they are not connected with the second pair by any groove or depression as in *Tr. fimbriatus.* The second pair are large deep subcircular pits completely isolated from the axial furrows, and lying at the base of the pseudo-frontal lobe and inside the line of the first pair of furrows. The third pair of large broad crescentic furrows begin anteriorly in pits and curve back to the meso-occipital furrow so as to embrace, as in *Tr. fimbriatus*, a basal ring less strongly marked than in that species, ending in a faintly impressed fourth pair of pits in the meso-occipital furrow. The lateral composite lobes are readily distinguishable, particularly in impressions of the surface of the head-shield, and extend back as depressed sub-lanceolate areas from the first lateral furrows to the base of the glabella, but they are less swollen and distinct than in *Tr. fimbriatus.*

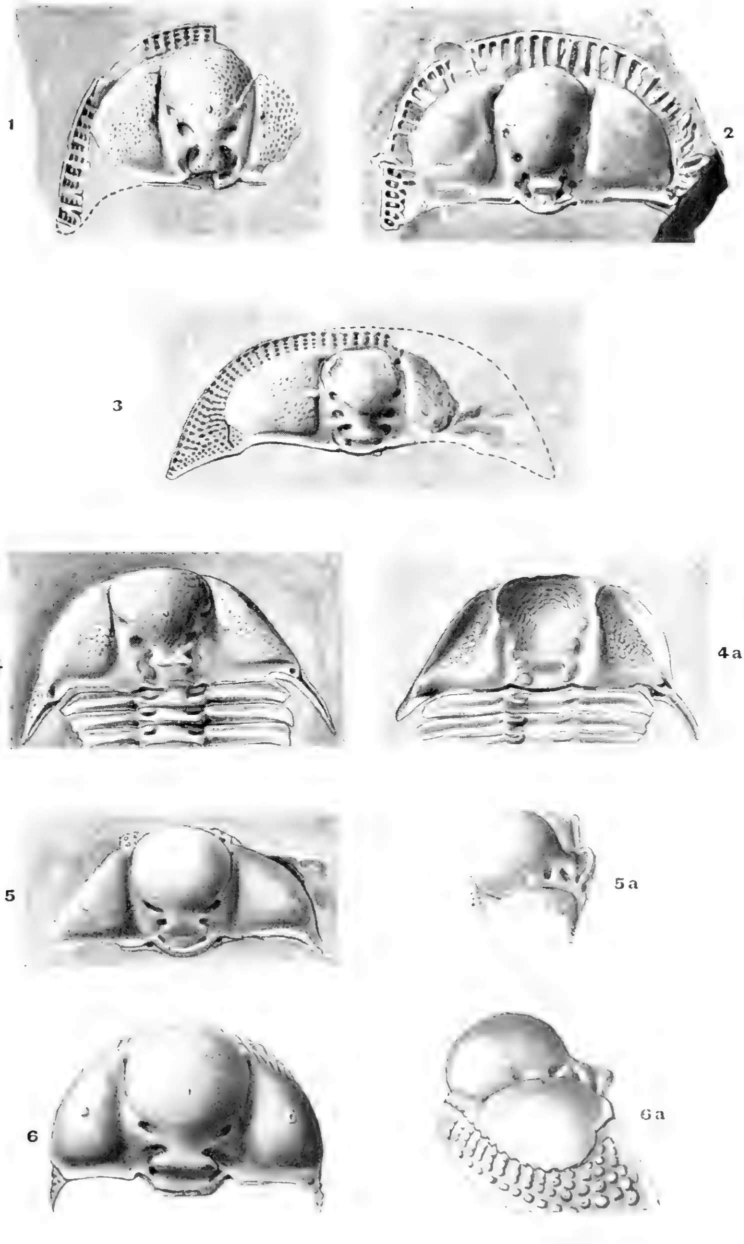
The axial furrows start anteriorly in well-marked pseudo-antennary pits, become less deep and wider behind the first lateral furrows, and curve in gently posteriorly. No sub-marginal pits or notches seem to be present at their posterior ends as in some species, but their position is marked by the size of the meso-occipital ring and its lateral extension outside the longitudinal line of the lateral glabellar pits.

In *Tr. Etheridgei*, Hicks,[2] the characters of the glabella and furrows appear to be closely similar.

Tr. Gibbsi, Salter,[3] is probably allied, but none of the specimens which I have examined allow the lobation of the glabella to be as completely determined as in the species above described, and Salter's figure is diagrammatic.

We pass now to *Tr. seticornis*, auctt., using the specific name in the broad sense common in this country. Specimens from the Sholeshook (Pl. XXVIII, Figs. 5, 5*a*), Slade, and Redhill Beds of Pembrokeshire and from the Ashgillian of the North of England show a well-differentiated swollen pseudo-frontal lobe, with the first furrows represented by shallow small pits at its sides close to the axial furrows and at about half its length. The second pair of segmental furrows consist of large deep completely isolated pits at the base of the pseudo-frontal lobe. The third pair are, as usual, in the same axial line as the second pair and are crescentic in form, beginning anteriorly in pits and ending behind in a fourth pair of pits in the

[1] Salter, Mem. Geol. Surv., vol. iii, p. 515, pl. xi B, fig. 4.
[2] Hicks, Quart. Journ. Geol. Soc., vol. xxxi, p. 182, pl. ix, fig. 6, 1875.
[3] Salter, Mem. Geol. Surv., vol. iii, p. 516, pl. xii, fig. 10.



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Glabella of *Trinucleus*.

meso-occipital furrow, thus bounding laterally a more or less marked basal ring. The stalk of the glabella is of a sub-cylindrical shape; it is well marked off from the pseudo-frontal lobe in front and from the depressed almost obsolete narrow composite lateral lobes, which have suffered such reduction as almost to escape notice, though they are still more clearly traceable in some specimens than in others. The posterior ends of the axial furrows, which have almost disappeared behind the pseudo-frontal lobe, being lost in the wide depression between the stalk of the glabella and the cheeks, are marked by a strong pair of sub-marginal pits, lying very close to the posterior edge of the head-shield, outside the axial line of the glabellar pits and at the sides of but behind the meso-occipital ring. Between successive thoracic segments there are similar pits in the axial furrows. It may here be remarked that the fact that the anterior width of the first and following rings of the thoracic axis is considerably greater than that of the stalk of the glabella indicates that this stalk does not really correspond to the total width of the axial (i.e. glabellar) portion of the head-shield. The sub-marginal intersegmental axial pits of the thorax as well as the sub-marginal pits of the head-shield thus lie in a longitudinal line outside the second and third pits of the glabella.

The pseudo-antennary pits in *Tr. seticornis* are always distinct and in their typical position.

The allied *Tr. Bucklandi*, Barr.,[1] as represented by the smaller specimens from Girvan[2] (Pl. XXVIII, Figs. 6, 6*a*; Pl. XXIX, Fig. 1) which appear to completely agree with Bohemian examples and to differ slightly from the larger specimens from Girvan attributed to the same species, has the pseudo-frontal lobe differentiated as in *Tr. seticornis*, and the first pair of lateral furrows of the glabella of the same character and in the same position. The second pair of furrows are not, however, simply pits, but form short, deep, transversely oblique furrows, bounding the pseudo-frontal lobe behind, but they do not arise quite from the axial furrows, though very near them, and they extend about one-third of the way across the width of the glabella on each side, deepening internally and ending abruptly. The third pair of furrows are also not simply isolated pits on the surface of the glabella, but are short, transverse, broad furrows arising nearly from the axial furrows with their inner ends deepest; they are also directed obliquely forward to the middle, and are only feebly connected behind with the deep fourth pair of pits in the meso-occipital furrow. The single lateral composite lobe is thus almost segmented and tends to be split up into imperfectly separated paired lateral lobes owing to the length of the second and third pairs of furrows, but the lobes are not clearly individualized. The lateral furrows are better developed and less reduced in this species than in the others. Owing to the weakness of the connexion between the third pair of furrows and the fourth pits, the basal ring is obscurely defined, but the stalk of the

[1] Barrande, Syst. Silur. Bohême, vol. i, p. 621, pl. xxix, figs. 10–17.

[2] Nicholson & Etheridge, Mon. Silur. Foss. Girvan, fasc. ii, p. 190, pl. xiii, figs. 14, 15, 20; Reed, Girvan Trilobites, 1903, pt. i, p. 10, pl. i, fig. 11.

glabella is swollen at its base and has a decided sub-nodular elevation at each side between the oblique third furrows and the meso-occipital stalk. The fourth pair of pits are large and deep. The sub-marginal pits at the posterior ends of the feebly impressed axial furrows are smaller than the others and lie outside the longitudinal lines in which they are arranged, as in *Tr. seticornis*. Though the axial furrows are indistinctly marked behind the pseudo-frontal lobe, and a wide depressed area on each side of the stalk of the glabella separates the latter from the cheeks, yet they can be traced with care the whole way back from the pseudo-antennary pits to the sub-marginal pits, and indicate the true ovoid shape of the entire glabella.

In the larger specimens of *Tr. Bucklandi* from Girvan (Pl. XXIX, Fig. 2), usually considered as the adult form of those above described, the first pair of lateral furrows is better marked, and the second and third pairs nearly meet at their inner ends; the lateral composite lobe is more differentiated and swollen along the axial furrows, and there is a small outer extra pit lying in or nearly in the axial furrows between the third and fourth pairs, as in *Tr. fimbriatus*. The formation of the basal ring, and the size and development of the fourth pits, the pseudo-antennary pits, and sub-marginal pits are as in the smaller form. Nicholson & Etheridge[1] noticed the first pair of lateral furrows in this species, and they were faintly shown in some of my figures of the species,[2] but their character and homology were not discussed. The general ovoid outline of the glabella is well seen in these specimens, the axial furrows being distinctly visible on each side, curving gently in with a slight convergence to the base of the glabella. In this form we may specially notice the strength of the lateral furrows, their approximate entry into the axial furrows, and the consequent tendency for the elongate composite lateral lobe to be resolved into its several pairs of lobes, the second pair of lateral lobes (between the second and third pairs of furrows) being nearly quite marked off and circumscribed. McCoy[3] in describing this species seems to have observed second, third, and fourth pairs of pits or furrows, for he says "the posterior half of the glabella [is] abruptly contracted to a narrow neck with a distinct neck-furrow [= meso-occipital furrow] and two short segmental furrows at each side [= second and third lateral furrows], the ends forming *three* deep punctures in casts". It may be mentioned here that the median tubercle on the pseudo-frontal lobe, which is so conspicuous in the smaller form, is much reduced and sometimes wanting in these larger specimens of *Tr. Bucklandi*.

Without attempting to discuss the form from Scania referred by Olin[4] to *Tr. Bucklandi*, it may be remarked that his figures indicate clearly that the glabella has an ovoid shape and includes lateral composite lobes scarcely differentiated from a median stalk, with well-developed true axial furrows.

[1] Nicholson & Etheridge, op. cit., p. 192.
[2] Reed, op. cit., pl. i, figs. 10, 13.
[3] McCoy, Syn. Pal. Foss. Woodw. Mus., p. 147.
[4] Olin, "Chasmopsk. o. Trinucleusskiffern i Skane": Medd. fr. Lunds Geol. Fältklubb, ser. B, Nr. i, 1906, p. 66, t. iv, figs. 1*a*, *b*.

The species *Tr. hibernicus*, Reed,[1] has the development of the stalk of the glabella even more advanced than in *Tr. Bucklandi* or *Tr. seticornis*, the sub-spherical pseudo-frontal lobe being sharply marked off from it, and the stalk itself being quite independently semi-cylindrical. Traces of the first pair of lateral furrows are visible as weak indentations close to the axial furrows; the second and third furrows are represented by deep transverse isolated pits, but the third pair has the curved extension backwards to enclose the distinct basal ring. Sub-marginal pits mark the posterior ends of the axial furrows, which are faintly traceable all the way back to them, but the composite lateral lobes are indistinct, though there is the narrow, elongated, depressed space on each side of the stalk occupying their place.

Tr. albidus, Reed,[2] from the Whitehouse Group (M. Bala) of Girvan, has an unusually large ovoid pseudo-frontal lobe and a well-defined semi-cylindrical stalk. The lateral furrows seem to be obsolete, and the composite lateral lobes and posterior part of the axial furrows have disappeared; but the fact that the meso-occipital ring extends on each side of the base of the stalk shows that the structure of the glabella is on the same plan. We must regard it as an extreme case of suppression of segmental and primitive characters.

We come now to a different group of species, including the somewhat varied assemblage of forms called *Tr. concentricus*, or named varieties of it. In these the stalk is not developed in the glabella and the lateral furrows are nearly obsolete.

The specimens of *Trinucleus* from the Bala Beds of the Onny River (Pl. XXIX, Figs. 3, 3*a*) usually referred to this species have an elongated ovoid glabella without any differentiation into a more swollen anterior, pseudo-frontal lobe and a depressed stalk; there is no sudden contraction in width, but the glabella decreases gradually in height and width to its base, the axial furrows being gradually convergent behind, but of uniform depth and strength. The glabella at first sight appears devoid of any traces of segmentation, but from the examination of a large number of specimens in different states of preservation it can be confidently asserted that three pairs of isolated lateral pits are present, though they are generally very faint or nearly obsolete. All of them lie inside the axial furrows and on the sides of the glabella. The first pair is usually obsolete; the second pair is very shallow, transversely oval, and half-way between the first and third pairs; the third pair is sometimes more of a furrow than a pit, and may obscurely mark off an incipient basal ring. A fourth pair of pits lying in the meso-occipital furrow (as in the *seticornis* group of species) is generally distinct, and lies in the same axial line as the other pairs of pits, but is not connected with the third furrows. Pseudo-antennary pits are always present at the anterior ends of the axial furrows, and sub-marginal pits at their posterior ends lying at the sides of the meso-occipital ring and outside the lines of the glabellar pits. A median tubercle on the glabella behind the level of the first pair of pits is present, and the meso-occipital segment is furnished with a horizontal nuchal spine.

[1] Reed, Geol. Mag., Dec. IV, Vol. II, p. 52, Pl. III, Figs. 2–7, 1895.

[2] Reed, Mon. Girvan Trilob., Suppl., 1914, p. 3, pl. i, figs. 1, 2.

In *Tr. favus*, Salter,[1] the glabella (Pl. XXIX, Fig. 4) has the same shape and characters as these Onny specimens of *Tr. concentricus*; three pairs of small shallow isolated pits can be more easily detected on the lateral slopes of the glabella, all unconnected with the axial furrows, the first ones being as much isolated as the others, but all are equidistant and sub-equally developed. A small fourth pair of pits in the meso-occipital furrow is also visible and pseudo-antennary pits at the anterior ends of the axial furrows. There is a median tubercle also on the glabella. Practically the segmentation and pitting is the same as in *Tr. concentricus* of the Onny River. *Tr. favus* is typically a Llandeilo form.

There is a form of *Trinucleus*, usually referred now to *Tr. concentricus*, which was separated by McCoy[2] as a distinct species which he called *Tr. gibbifrons* (Pl. XXIX, Figs. 5–7). The type-specimen of it cannot be found, but there are several specimens in the Sedgwick Museum from the Bala Beds of Allt yr Anker, Dinas Mawddy, and Pen y Craig, which were labelled by McCoy as *Tr. gibbifrons* and possess the characters which he described. In this form the glabella is shorter, broader, and more inflated than in the Onny River *Tr. concentricus*; the anterior part of the glabella is somewhat independently swollen into an incipient pseudo-frontal lobe; the posterior and shorter part of the glabella is slightly contracted at the base of this lobe and rather suddenly depressed, suggesting the formation of a stalk. The first pair of lateral pits is very weak and often scarcely discernible, indenting the sides of the anterior swollen portion; the second pair is likewise very faint or obsolete. There are then two much more distinct small sharply marked deep pits on each side of the base of the glabella; the anterior of these pits lies almost in the axial furrows and probably corresponds with the third pair in *Tr. concentricus* and others, but must represent the outer instead of the inner ends of these furrows (see remarks on *Tr. Goldfussi* below); between this pair a slight annular basal swelling of the glabella is noticeable, suggesting the basal ring of *Tr. Bucklandi*, etc. The posterior pair of pits apparently correspond with the fourth pair in the meso-occipital furrow, and are rather more inwardly situated than the third pair. The pseudo-antennary pits at the front ends of the axial furrows and the sub-marginal pits at their posterior ends are well marked. The axial furrows themselves are wider and less deeply impressed towards the base of the glabella, but there are no composite lateral lobes and the axial furrows plainly bound the glabella for its whole length and width. There is no horizontal nuchal spine to the meso-occipital ring, but a strong pointed median tubercle or short vertical spine is present on this ring. A median tubercle also is present on the swollen anterior part of the glabella.

We may regard this form, *Tr. gibbifrons*, as belonging to a parallel line of development to *Tr. seticornis* and its allies, but not directly connected with it. The inception of a pseudo-frontal lobe and stalk

[1] Salter, Mem. Geol. Surv., vol. ii, pt. i, p. 350, pl. ix, fig. 3; vol. iii, p. 517, pl. xiii, fig. 9; dec. vii, pl. vii, p. 6.

[2] McCoy, Syn. Pal. Foss. Woodw. Mus., p. 145, pl. i E, figs. 14, 14*a*.

and of a basal annular swelling are points of resemblance in the glabella, but the furrows and lobation are quite different.

The Bohemian species *Tr. Goldfussi*, Barr.,[1] of which I have examined nearly a dozen examples of the head-shield, appears to furnish an explanation of the two pairs of small but deep and well-marked pits at the base of the glabella, which I have described above in *Tr. gibbifrons*. For in *Tr. Goldfussi* there are, in addition to these small deep pits, three pairs of very shallow isolated pits of larger size and set at equal distances apart on the flanks of the glabella, as in the Onny River specimens of *Tr. concentricus*. These pits are only rarely visible, but where present the third pair is continued back by very weak furrows to the small deep pits in the axial furrows, thus showing that these pits may be regarded as marking the outer ends of the third lateral furrows. Behind them come the similar small deep pits in the meso-occipital furrow, as in *Tr. gibbifrons*. These two pairs of small pits are shown in Barrande's figures of *Tr. Goldfussi* and seem to be generally developed in all its allies.

In *Tr. Nicholsoni*, Reed,[2] the glabella has the elongated ovoid shape of *Tr. concentricus* (Onny River form), narrowing gradually behind, but the anterior part is more swollen and there is a median tubercle as in *Tr. gibbifrons*. The axial furrows are very deep and converge regularly behind without any contraction; the first and second furrows are very shallow faint depressions in the axial furrows, indenting the base of the sides; the third and fourth pairs of pits are sharp and deep, like those in *Tr. gibbifrons*, and there is likewise a weak basal annular swelling with low lateral nodules. A nuchal spine is present as in *Tr. concentricus*. Undoubtedly this species is closely connected with the latter.

With regard to the distinct species or varieties of *Tr. concentricus* described by Portlock from Tyrone, we can only speak with certainty of the form known as *Tr. concentricus*, var. *elongatus*,[3] so far as the characters and lobation of the glabella are concerned. This form has a long sub-pyriform glabella much like that of the Onny River *Tr. concentricus* in general shape; the pseudo-antennary pits are distinct; there are no traces of any first or second pairs of furrows or pits; two pairs of small deep, rather closely placed pits at the base of the glabella represent the third and fourth pits, the anterior pair of which lie in the axial furrows, the posterior pair rather further inwards and in the meso-occipital furrow. Both pairs are deep and subcircular. Sub-marginal pits are also present, and the meso-occipital ring bears a sharp median tubercle.

The Girvan species *Tr. subradiatus*, Reed,[4] from the Balclatchie Beds, possesses a glabella which in its general shape (apart from its carination) resembles that of *Tr. concentricus* of the Onny River, and the meso-occipital ring has likewise a horizontal nuchal spine. The

[1] Barrande, Syst. Silur. Bohême, i, p. 628, pl. xxx, figs. 29–40; pl. xxxv, figs. 30, 31.

[2] Reed, Geol. Mag., Dec. V, Vol. VII, p. 212, Pl. XVI, Figs. 1–9, 1910.

[3] Portlock, Geol. Rep. Londond., p. 263, pl. i B, fig. 7; B. Smith, Proc. Roy. Irish Acad., xxvi, B, 9, p. 127, pl. viii, figs. 3, 4, 1907.

[4] Reed, Girvan Trilobites, 1903, pt. i, p. 12, pl. ii, figs. 1–6.

first two pairs of lateral furrows of the glabella, though very short and often mere notches indenting the sides of the glabella, start from the axial furrows; the third pair is longer and oblique, the outer end of each furrow being marked by a deep pit set far back in the axial furrow. There is a fourth pair of pits transversely oval in shape and set rather further inwards in the meso-occipital furrow; and sub-marginal and pseudo-antennary pits are likewise present. Traces of a faint basal ring are generally visible.

Several British species are not sufficiently known to enable us to discuss adequately their glabellar segmentation. Such are *Tr. latus*, Portl., *Tr. radiatus*, Murch., *Tr. Thersites*, Salter, and *Tr. Lloydi*, Murch.

In the case of *Tr. radiatus*, Murch.,[1] the second and third lateral furrows seem represented by two deep triangular pits, of which the anterior pair is situated behind the middle of the glabella, and the third pair has a slight connecting groove across the base of the glabella, marking off a basal ring.

Salter's[2] figures of *Tr. Lloydi* show a feebly marked, narrow, elongated, lateral composite lobe on each side of the posterior half of the glabella, and in Fig. 1* a decided basal ring, but he only mentions "a slight longitudinal depression on each side" (marking off the lateral lobe) and "one obscure lateral sulcus above the neck-furrow" at its base (=the third lateral furrow). The condition of the lateral composite lobes recalls that found in *Ampyx nudus*, Murch.

Tr. Thersites, Salter,[3] shows no stalk and no furrows on its narrow compressed carinate glabella; this species has never been figured, and the type-specimens are hardly sufficient for an adequate specific diagnosis.

EXPLANATION OF PLATES.

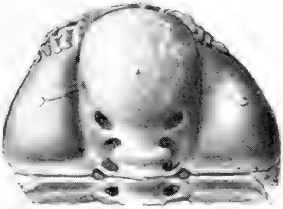
Plate XXVIII.

Fig. 1. *Trinucleus fimbriatus*, Murchison. × 3. Llandeilo Beds: Pen Cerrig, Builth.
,, 2. Ditto. × 2. Same horizon and locality.
,, 3. Ditto. × 3. Same horizon and locality. McCoy's figured specimen, Syn. Brit. Pal. Foss. Woodw. Mus., pl. i E, fig. 16.
,, 4. *Trinucleus Murchisoni*, Salter. × 2½. Arenig Series: Tasker Quarry, near Shelve.
,, 4*a*. Ditto. × 2½. Impression of same specimen.
,, 5. *Trinucleus seticornis*, Hisinger. × 2½. Sholeshook Limestone: Sholeshook, Pemb.
,, 5*a*. Ditto. × 2½. Side view of same specimen.
,, 6. *Trinucleus Bucklandi*, Barrande (small form). × 2½. Drummuck Group: Thraive Glen, Girvan. Mrs. Gray's Collection.
,, 6*a*. Ditto. × 2½. Side view of same specimen.

Plate XXIX.

Fig. 1. *Trinucleus Bucklandi*, Barrande (small form). × 2½ (with one thoracic ring attached). Drummuck Group: Thraive Glen, Girvan. Mrs. Gray's Collection.
,, 2. Ditto (large form). × 1½. Same horizon and locality. Mrs. Gray's Collection.

[1] Murchison, Silur. Syst., pl. xxiv, fig. 3.
[2] Salter, Mem. Geol. Surv., dec. vii, pl. vii, 1853 (the figures are largely restorations).
[3] Ibid., p. 7.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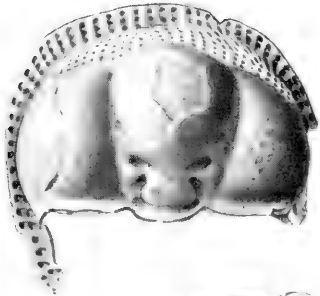
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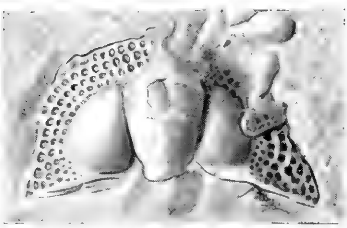
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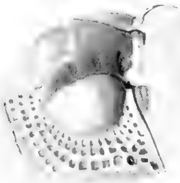
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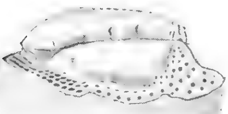
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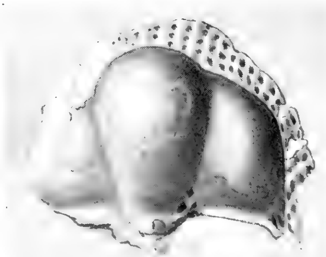
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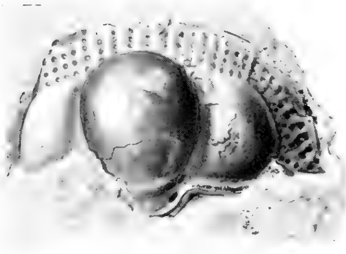
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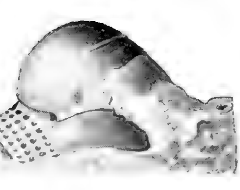
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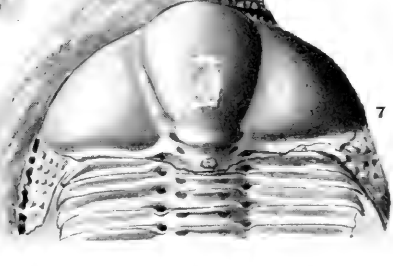
7

T. A. Brock del.

Glabella of *Trinucleus*.

FIG. 3. *Trinucleus concentricus* (Eaton). × 2. Middle Bala: Onny River, Shropshire.
,, 3*a*. Ditto. × 2. Side view of same specimen.
,, 4. *Trinucleus favus*, Salter. × 3. Side view. Llandeilo Beds: Llandeilo.
,, 5. *Trinucleus gibbifrons*, McCoy. × 2½. Middle Bala: Wales. One of the specimens named and labelled by McCoy.
,, 5*a*. Ditto. × 2½. Side view of same specimen.
,, 6. Ditto. × 2½. Middle Bala: Gelli Grin.
,, 7. Ditto? × 2½. Starfish Bed, Thraive Glen, Girvan. Mrs. Gray's Collection.

N.B. All the specimens, except mentioned otherwise, are in the Sedgwick Museum, Cambridge.

(*To be continued.*)

V.—THE ZONE OF *OFFASTER PILULA* IN THE SOUTH ENGLISH CHALK.

By R. M. BRYDONE, B.A., F.G.S.

PART I.

IN the year 1911 Mr. Griffith and I[1] proposed to recognize in Hants three divisions of the Chalk intervening between the zones of *Marsupites testudinarius* and *Belemnitella mucronata*, and then known as the zone of *Actinocamax quadratus*. These divisions we were not jointly prepared to treat as more than subzonal. In the year 1912 I[2] defined the lower and middle divisions very closely and described them in detail, and demonstrated that the upper boundary of the middle division was a strongly marked break. This break I regarded as of zonal importance, and I therefore separated the lower and middle divisions from the upper as subzonal divisions of a new zone of *Offaster pilula*. I was also able to say that the features of the new zone in Hants were exactly reproduced in the Sussex cliffs and to cite as presumptive evidence that it was equally recognizable in Wiltshire a statement by Dr. Blackmore that the divisions proposed in 1911 held good round Salisbury. The object of this paper is to trace the new zone in detail in the more accessible cliff sections of the old zone of *A. quadratus* in the South of England.

The zone of *O. pilula*, as established for Hants (on inland sections only), was estimated to be about 105 feet thick, made up as follows:—

			Feet
Zone of *O. pilula*.	Subzone of abundant *O. pilula*	Upper belt of *O. pilula*, with a pair of marl seams about 18 inches apart as its base and a marl seam (succeeding about 3 feet of chalk yielding *O. pilula* of exceptional size) as its top	about 13
		'Middle belt,' with few *O. pilula* and apparently no marl seams	about 20
		Lower belt of *O. pilula*, bounded above and below by marl seams	about 12
	Subzone of *E. scutatus*, var. *depressus*	Chalk with *O. pilula* occurring erratically and becoming very scarce towards the bottom; *Echinocorys scutatus*, var. *depressus*, in the upper part; *E. scutatus*, var. *tectiformis*, and abundance of *Ostrea Wegmanniana* and *O. incurva* (often in bunches) in the lower part	about 60
			About 105

[1] *The Zones of the Chalk in Hants*, London, Dulau & Co., 1911.
[2] *The Stratigraphy of the Chalk of Hants*, London, Dulau & Co., 1912.

Other noteworthy fossils of the zone are *Ostrea canaliculata*, var. *striata*,[1] and *Bourgueticrinus* Forms 1 and 2, very characteristic of the subzone of abundant *O. pilula*; *Echinocorys scutatus*, var. *cinctus*, so characteristic of the middle belt of the same subzone that I propose to call it the *Cinctus* belt; *E. scutatus*, var. *truncatus*, confined to the lower belt of the same subzone and a few feet below it; *Terebratulina Rowei*, reappearing at the base of the same subzone after disappearing at the top of the zone of *Marsupites*, and occurring chiefly in the lower belt, but occasionally also in the middle and upper belts; *Rhagasostoma palpigerum*, strongly associated with the subzone of abundant *O. pilula*; a free ramose form of *Porosphæra* with thick flattened branches, perhaps confined to the same subzone; *Bourgueticrinus* Form 5, reappearing for a short time in the upper part of the subzone of *E. scutatus*, var. *depressus*, after disappearing at the top of, if not some way down in, the zone of *Marsupites* and *Bourgueticrinus* Form 6, a very reliable guide to the subzone of *E. scutatus*, var. *depressus*, and particularly its lower beds. To these may be added a darkish, thick-shelled, and often gracefully curved form of *Ostrea incurva*, which is very closely associated with the upper belt of the subzone of abundant *O. pilula* and almost confined to it.

I. Sussex.

From Black Rock, Brighton, to Newhaven, a distance of some 7½ miles, there is a continuous cliff. This cliff is composed entirely (except for about a mile at the Brighton end, and about half a mile in Friars Bay) of chalk of the zones of *O. pilula* and *A. quadratus*, lying in gentle folds.

A. *Subzone of E. scutatus, var. depressus.*

The base of this subzone no doubt comes in at the top of the cliff at or near Black Rock, and a gentle easterly dip brings it down to the base of the cliff a little to the east of Roedean School. This easterly dip continues towards Rottingdean, but without ever bringing the succeeding subzone in reach at the base of the cliff. A little west of Rottingdean the beds become practically level and so continue across the gap and part of the way through East Hill. Close to Saltdean Bottom the beds rise in a slight anticline, which culminates at Saltdean Bottom and brings up on the foreshore, but not into the cliff, the highest beds of the zone of *Marsupites*. The anticline has a very flat top and the beds remain practically horizontal for about half a mile; they then dip steadily eastwards and the top of the subzone passes below the foot of the cliff just east of the sewer at Portobello. The subzone is brought up again by the Friars Bay anticline, coming into the cliff about a quarter of a mile east of Friars Bay with a gentle dip which does not carry the top of the subzone out of reach until the west horn of Friars Bay is reached. The dip then increases and the whole thickness of the subzone passes up into the cliff, together with some 8 feet of the zone of *Marsupites*, before a series of minor faults appear and so neatly counteract the

[1] The mystery surrounding the origin of this most useful varietal name has not been cleared up by Mr. Woods' recent monograph. It probably originated with Dr. Blackmore.

effect of the anticline as to prevent any further chalk of the zone of *Marsupites* from coming into the cliff. After about half a mile the beds begin to dip eastwards again. and the whole thickness of the subzone passes out of the cliff into the foreshore in the course of a quarter of a mile at Old Nore Point. The syncline into which the beds are here passing is a very gentle one and culminates just west of the miniature rifle butts under Castle Hill, but the gentle westerly dip which prevails from this point to Newhaven harbour is just as likely to be due to the change of direction of the cliff giving a section along the general dip off the Wealden axis as to the approach of another anticline transverse to the general coastline. It certainly does not bring the subzone up into the cliff again. There may well be an anticline bringing up the subzone in the middle of the Ouse Valley; but in any case when the chalk reappears on the coast at the Buckle Inn, near Seaford, this subzone has sunk far below beach level and is only seen again in Seaford Head.

[The various folds which have been indicated may be labelled from west to east as—Rottingdean syncline, Saltdean anticline, Telscombe syncline, Friars Bay anticline, Castle Hill syncline, Seaford syncline, and Seaford Head anticline. They are obviously capable of being referred to just such a system, if not a continuation of the same system, of folds, oblique and secondary to the Wealden axis, as I have suggested in Hants. The Seaford syncline has been shown by Dr. Elsden to run inland obliquely to the coastline, and Meeching Quarry, Newhaven, almost certainly gives a similarly oblique line of prolongation for the Friars Bay anticline.]

The subzone varies very little lithologically in these exposures. It is 60 feet thick between Brighton and Rottingdean and again in Friars Bay and 64 feet in the Saltdean anticline, and the minute lithological details correspond so closely that it can hardly be doubted that the marl beds treated in the following section as corresponding are actually continuous over the intervening areas. Even at Seaford Head there appears to be an exact correspondence bed by bed and marl seam by marl seam, though the thicknesses of the individual beds are uniformly reduced, perhaps owing to local compression in the course of folding.

This subzone reproduces very accurately in Sussex the features ascribed to it in Hants. The lower 25 feet or so are characterized by *E. scutatus*, var. *tectiformis*, *Bourgueticrinus* Form 6, and *O. Wegmanniana* and *O. incurva* in abundance. The next 25 feet or so are characterized by *E. scutatus*, var. *depressus*, and *Bourgueticrinus* Form 5, while in the upper 10 feet or so *E. scutatus* passes rapidly into the var. *truncatus*, which becomes fully established before the subzone ends. The section indicates the lowest bed in which I have yet found *O. pilula*. It occurs in all higher beds.

It is necessary to deal with the grounds on which I have fixed my base of the subzone. As I have found normal (small and smooth) *Marsupites* plates in the cliff at Friars Bay, immediately below the lowest marl seam shown in my sections, it is clear that the zone of *Marsupites* is properly carried up to that seam, and the only question is as to the 7 ft. band of chalk separating it from the one I have taken as the top of the zone. This band is accessible for a long distance in a wave-beaten section at Friars Bay, for a short distance in a favourable condition near Brighton (where the upper boundary is hardly marly and is little more than a parting), and for some distance, in parts of which it is in fair condition, in Meeching Quarry, Newhaven. I have not yet found even a small specimen of a normal *Marsupites* plate in this band; but small and dwarf Crinoid brachials, such as are otherwise only found in association with *Uintacrinus* or *Marsupites*, range all through this band and are fairly abundant, while occasionally very small Crinoid plates are found which may be indistinguishable from plates of *Marsupites* except for their smallness or may be practically oblong with about $\frac{1}{6}$ in. of their length flat at each end and the remainder arched. (I have once or twice found similar plates in Hants in beds which probably occupied the same position, just above the highest undoubted plates of *Marsupites.*) *Terebratulina Rowei* is also present throughout this band and in an abundance which seems quite unusual to me. At the top of this band of chalk *T. Rowei* and the dwarf plates disappear absolutely, and the brachials disappear so nearly absolutely that I have only met with very few above this band, all of which were in the lowest foot of the succeeding bed. I have also from this band one pyramidate *E. scutatus*, which if not typical of the var. *elevatus* is very much nearer to it than to the var. *tectiformis*. On these grounds I have attributed this band to the zone of *Marsupites*. *Bourgueticrinus* Form 5 has not yet been found in this band nor in the upper beds in which undoubted plates of *Marsupites* occur, and this confirms an impression I have derived from the Hants sections that it disappears before the top of the zone of *Marsupites* is reached. It is curious how consistently it seems to anticipate *T. Rowei*, which is commonly treated as having the same range. Thus *Bourgueticrinus* Form 5 is well established some way below the *Uintacrinus* band; *T. Rowei* appears to come in only a very little way below the *Uintacrinus* band; *Bourgueticrinus* Form 5 disappears apparently in the course of the zone of *Marsupites*, *T. Rowei* at its end. *Bourgueticrinus* Form 5 reappears in the middle of the subzone of *E. scutatus*, var. *depressus*, and does not seem to outlive it; *T. Rowei* does not reappear until the subzone of abundant *O. pilula*, and persists almost, if not quite, all through it.

It will be observed that the lithological features by which I have divided up the subzone are exclusively marl bands. This does not mean that I do not attach any value to lines of flint as permanent features, for I hold that they are very often persistent enough to be very serviceable. A conspicuous instance may be found in the bed I have treated as the highest bed of the *Marsupites* zone; this bed between Brighton and Rottingdean contains a line of flints from 1 foot to 18 inches down and another 3 feet lower; its flints are distributed in exactly the same way in Friars Bay, 5 miles away, and again a mile further on in Meeching Quarry, Newhaven, and at Seaford Head.

A good deal of scorn has been heaped upon the idea of lines of flint being sufficiently persistent to be of use as indices to horizon, but it will be found that many of the cases cited are really irrelevant, being cases of the impersistence of tabular veins. The presumption being that these were formed in cracks after the chalk had consolidated, it is obvious that they have no necessary connection with bedding planes, however much they may tend to follow them, nor can their impersistency be relevant to interstratified lines of flints. At the same time marl seams as a rule are more constant than lines of flints in their individual characters : that is to say, a marl seam will retain the same degree of thickness and definiteness over a long distance, while lines of flints will often vary from wide and closely set to thinly strung out in the course of a few feet. Marl seams are therefore much more useful than flint lines in tracing the effect of the dislocations which are so often met with. I also regard them as no less persistent and as a rule more persistent than flint lines over long distances. An admirable instance is to be found in the sections under discussion in the marl bed I have called the "2 inch Marl". This bed consists of from 2 to 3 inches of solid marl, and forms a conspicuous feature in the cliff and a ready guide to the general position of the upper boundary of the subzone; it comes in just above the Roedean School tunnel and occurs with perfect regularity right away to Seaford Head. I have, therefore, on all three grounds of constancy in thickness, definiteness, and persistency, come to attach the chief importance among lithological features to marl seams.

SECTIONS THROUGH THE SUBZONE OF *E. SCUTATUS*, VAR. *DEPRESSUS*, AFFORDED BY THE SUSSEX CLIFFS.

		Brighton to Rottingdean.	Saltdean to Telscombe.	Friars Bay.	Seaford Head.
	Marl seam marking base of subzone of abundant *O. pilula*.	ft. in.	ft. in.	ft. in.	ft. in.
Subzone of *E. scutatus*, var. *depressus*.	Chalk	4 0	4 6	4 3	2 6
	Thick marl seam ("2 inch Marl")				
	Chalk	14 0	14 0	13 3	10 6
	Upper of a pair of marl seams, 15 inches apart.				
	Chalk	7 0	7 0	6 6	5 6
	Upper of a pair of marl seams, 15 inches apart.				
	Chalk	8 9	9 0	8 6	7 4
	Strong marl seam.				
	Chalk	10 9	10 9	8 9	7 10
	Marl seam.				
	Chalk yielding two *O. pilula* . .	6 0	8 6	7 10	7 2
	Marl seam.				
	Chalk	5 0	6 0	6 0	5 8
	Marl seam.				
	Chalk	4 6	4 6	4 9	3 6
		60 0	64 3	59 10	50 0
	Thin marl seam.				
Zone of *Marsupites*.	Chalk with flint seam at 1–1½ feet down, and another at 4–4½ feet down .	7 0	—	6 9	7 3
	Marl seam.				
	Chalk yielding plates of *Marsupites* .	+8 0	—	+8 0	+8 0

B. *Subzone of abundant O. pilula.*

The lower boundary of this subzone comes into the cliff just opposite Roedean School, and the upper boundary also undoubtedly comes in towards the top of Beacon Hill just west of Rottingdean. Rottingdean Gap cuts clean through this subzone and into the one below, but it reappears in East Hill, where its full thickness is present and there is also room for a substantial amount of *quadratus*-chalk. Saltdean Bottom cuts again clean through this subzone, but it is clearly present in Portobello cliff in its full thickness, sinking gradually eastwards as the Saltdean anticline passes into the Telscombe syncline. In the centre of the Telscombe syncline the whole subzone passes out of the cliff on to the foreshore, the upper boundary descending several feet below high-water mark; but it soon rises into the cliff again, and then monopolizes the base of the cliff most of the way to the west end of Friars Bay and does not rise wholly out of reach until the west horn of Friars Bay is turned. Over the Friars Bay anticline it is in the upper part of the cliff, but never quite reaches the top of the cliff; even Chene Gap fails apparently to cut quite down to it. At Old Nore Point it comes down to beach level and the greater part of it passes rather quickly out of the cliff on to the foreshore; but the rapid diminution in the dip as the Friars Bay anticline passes into the Castle Hill syncline keeps the upper boundary just above beach level. From this point to Newhaven the dip (westwards) is very slight, but gradually brings the upper belt and then the middle belt and finally perhaps the top of the lower belt of the subzone into the cliff.

The subzone has sunk again below the surface when the chalk reappears above beach level at Buckle Inn, but between that point and Seaford it used to be recognizable on the foreshore at low water. At Seaford Head it reappears for the last time, emerging from behind the sea-wall with its upper boundary about 12 feet below the esplanade level and passing rapidly up through the cliff and out at the top.

The subzone is so uniform in its physical characters that the following section will apply to every occurrence of it.

Subzone of abundant *Offaster pilula* in the Sussex Cliffs.

Chalk of zone of *A. quadratus*.

Subzone	Belt	Bed	ft.	in.		ft.	in.
		Marl seam.					
Subzone of abundant *O. pilula*.	Upper belt of *O. pilula*.	Chalk with very large *O. pilula* . .	1	0	to	1	6
		Flint seam.					
		Chalk with large *O. pilula*	1	6		2	0
		Marl seam.					
		Chalk	2	6		2	9
		Marl seam.					
		Chalk	6	6		7	6
		Marl seam.					
		Chalk	1	0		1	6
		Marl seam.					
	Cinctus belt.	Chalk with very few marl seams (except at Seaford Head, where there are five)	20	0		22	0
		Flint seam, often tabular.					
	Lower belt of *O. pilula*.	Chalk with varying seams of marl and flint	10	6		11	0
		Marl seam.					
		Chalk	1	3		1	6
		Marl seam.	44	3	to	49	9

Chalk of subzone of *E. scutatus*, var. *depressus*.

The subzone in Sussex corresponds palæontologically in the closest way with the same subzone in Hants. The only guide fossil for Hants which may be rare in Sussex is *Terebratulina Rowei*; but several specimens have been found, and their relative scarcity is probably due to the absence of clean unbattered surfaces, which alone are favourable for finding so small a fossil.

In the matter of lithological details the upper belt of *O. pilula* offers some strikingly minute correspondences. It is invariably the rule in Hants as it is in Sussex that the lowest 12 to 18 inches are marked off by marl seams, and that the highest 3 feet or so, characterized by *O. pilula* of exceptional size and shape, are marked off by marl seams (with a flint seam almost always about midway).

C. *Zone of A. quadratus.*

All the synclines which have been defined contain as their highest element outliers at least of this zone. In the relatively shallow Rottingdean syncline the outlier is split by Rottingdean Gap into two parts, which occupy the summits of the hills east and west of Rottingdean and are quite inaccessible from the shore; but a fair though scanty section through some of the lower beds is afforded by the road cutting down the east side of East Hill.

At the west edge of the Telscombe syncline there is probably an outlier of this zone on the east slope of Portobello Hill. In the centre of the Telscombe syncline we get the base of the zone descending to some 8 feet below high-tide level, but unfortunately there is no beach here, and so only a small thickness of wave-washed chalk becomes accessible. (It is, however, interesting to note that the 12 feet or so which is accessible agrees most closely in lithological details with the Newhaven and Seaford Head sections.) The deepest part of the syncline is about a quarter of a mile west of Telscombe Stairs. Here the cliff, which is practically solid chalk, just exceeds the 100 feet contour and the top of the zone of *O. pilula* is about 7 feet above low-water mark, so that there must be over 90 feet of the zone of *A. quadratus* preserved. The bed-to-bed thickness of the greater part can only be estimated here but the lower 70 feet can be measured at Telscombe Stairs.

From Telscombe to Newhaven Harbour this zone never ceases to occupy the top of the cliff. In the Castle Hill syncline it comes down almost to beach level (here a few feet above high-water mark). The lower beds are easily accessible (though very dirty) over a long distance, and a considerable thickness, amounting to about 55 feet, is measurable at Burrow Head, while a further 15 feet (about) appears to be preserved at the top of the cliff in the centre of the syncline.

When chalk reappears on the east side of the Ouse Valley at the Buckle Inn it is chalk of this zone which is at the surface and composes the low cliffs immediately round the Buckle Inn. A fair section of probably rather higher beds used to be furnished by a low cliff between here and Seaford, which is now sloped, and hidden in the lower part by a sea-wall.

Finally we come to the Seaford Head section, easily measurable owing to the dip. The full thickness preserved here beneath the

Tertiaries is just about 55 feet, as at Burrow Head, so that there are at least 35 feet of chalk at Telscombe and some 15 feet in the centre of the Castle Hill syncline higher than anything at Seaford.

The following general section will apply to all the chalk of this zone:—

ZONE OF *A. QUADRATUS* IN THE SUSSEX CLIFFS.

	ft.	in.		ft.	in.
Chalk inaccessible at Telscombe, estimated at .		30		0	
Chalk measured at Telscombe, inaccessible at Newhaven and only partly preserved at Seaford .		19		0	
	49	0		49	0
Strong flint seam.					
Chalk	5	6	to	7	0
Strong flint seam.					
Chalk	6	0		6	6
Strong flint seam.					
Chalk	11	0		13	0
(In the upper part of this bed there may be a thin seam of *O. pilula* at Newhaven, of which there is no trace at Seaford. The Telscombe section affords no test.)					
Strong flint seam.					
Chalk	9	0		10	3
(There are two marl seams in this bed at Telscombe and traces of marl seams at Newhaven, but none at Seaford.)					
Strong flint seam.					
Chalk	6	0		6	0
(There is a thin marl seam just above the base of this bed at Newhaven.)					
Broad seam of loosely set flints.					
Chalk	3	6		5	6
Weak marl seam.					
Chalk	1	6		2	6
Flint seam.					
Chalk	1	0		1	6
	92	6	to	101	3
Marl seam marking top of zone of *O. pilula*.					

Attention is called to the fact that the lowest 3 to 4 feet are marked off by a marl seam and embrace a flint seam. This will be found to be repeated in the Isle of Wight, and it is also the case at Hursley, Compton, and West Meon in Hants, where the bounding marl seam is very faintly marly and little more than a parting. It forms a striking combination with the even more widely constant bed at the top of the zone of *O. pilula* and immediately preceding it.

There is little to be said about the general fauna of the zone, only the lowest beds being in practice accessible for any distance, and these, as I have previously pointed out,[1] being characterized chiefly by the gradual dying out of such of the leading fossils of the subzone of abundant *O. pilula* as succeeded in outliving it. Thus, while

[1] "The proposed recognition of two stages in the Upper Chalk": GEOL. MAG., February, 1913, p. 61.

Terebratulina Rowei and *Echinocorys scutatus*, var. *truncatus*, have disappeared apparently for good, and *Offaster pilula* though theoretically a possibility is in practice absent, the other leading fossils of the subzone of abundant *O. pilula* have lives of varying but probably always brief duration in the base of this zone. *Ostrea canaliculata*, var. *striata*, for instance, is strongly represented in the lowest 6 feet and then apparently disappears completely. *Bourgueticrinus* Forms 1 and 2 continue to occur sparingly for about 12 feet (accompanied by transitions to forms which establish themselves later) and then disappear. [*Bourgueticrinus* Form 3 I think must be withdrawn from the list of characteristic forms of the subzone of abundant *O. pilula*. It is specially abundant in that subzone, but both appears before it and persists in occasional instances long after it, and can only be treated as a subsidiary guide fossil, for which a subzone so strongly characterized has no need.] Mr. Spencer's remarks[1] as to the affinity of giant ossicles of *Metopaster Parkinsoni* and *Calliderma Smithiæ* for the zone of *O. pilula* (*sub nom.* "subzone of *O. pilula*") and the lower beds of the zone of *A. quadratus* (*sub nom.* "subzone of *A. quadratus*") give interest to the question exactly how far up the zone of *A. quadratus* these forms range. The giant ossicles of *Metopaster Parkinsoni* seem to culminate at from 26 to 33 feet; only one has been found yet above this level, i.e. at about 43 feet. They have never yet been found in the upper part of the zone. The large ossicles of *Calliderma Smithiæ* similarly referred to[2] have not been found more than 12 feet up.

The only striking feature is *Hagenowia rostrata*. This fossil sets in as soon as the zone of *O. pilula* has ended and becomes sufficiently abundant to serve as a guide fossil. Unfortunately the body of the urchin is never preserved, the rostra having at most a little film of shell attached. It is interesting to note that a rostrum has recently been found in this zone, apparently for the first time in Hants, at Compton, near Winchester, and in precisely the same relative position in the zone.

Belemnites are very scarce in the zone of *O. pilula* except perhaps at the base, where *A. granulatus* occurs sparingly but fairly consistently. It is therefore only where there is a large area available that there is any prospect of obtaining, even in the course of years, enough specimens to afford any clue to the range of the various species in that neighbourhood. The Sussex coast-section of the zone is the only one which fulfils this condition, and it will not be out of place to give the Belemnites at this point the special consideration which they have earned by their value as zonal guides elsewhere.

Experience prepares us for the occurrence of four Belemnites, *A. granulatus*, *A. quadratus*, *A. verus*, and *Belemnitella lanceolata*. Of these *B. lanceolata* and *A. verus* have not been found yet, except for an imperfect Belemnite at the top of the zone of *E. scutatus*, var. *depressus*, which may have been *A. verus*, and they are only likely to

[1] W. K. Spencer, "The Evolution of the Cretaceous Asteroidea": Phil. Trans. Roy. Soc. Lond., ser. B, vol. cciv, p. 112.

[2] W. K. Spencer, op. cit., p. 218.

occur as isolated curiosities. Interest is therefore concentrated on *A. granulatus* and *A. quadratus*.

All my specimens, not a large number, from the *lower* part of the subzone of *E. scutatus*, var. *depressus*, are too imperfect to be identified; they may with all probability be assumed to be *A. granulatus*, as Dr. Rowe appears to have found at that level Belemnites identifiable as that species, and there is no evidence yet that *A. quadratus* ever ranged so low.

At a point 25 feet below the top of the subzone, i.e. in its upper half, I found a specimen broken but complete except for slight fraying of the edges of the alveolar cavity. Mr. Crick and Dr. Blackmore both regard this specimen as intermediate between *A. granulatus* and *A. quadratus*, Mr. Crick saying "The specimen, although possessing affinities with *A. quadratus*, seems to me to be more closely related to *A. granulatus*"; and Dr. Blackmore saying that it "is, I believe, *A. quadratus*, although the general contour of the specimen is rather like that of *A. granulatus*, but the depth and form of the phragmaconal cavity is that of the former species". That the special features of the specimen are not accidental is shown by the fact that some 4 miles away I found about 6 feet higher in the subzone the upper half of a Belemnite with the alveolar cavity in perfect preservation and agreeing exactly with the specimen submitted to Mr. Crick and Dr. Blackmore. If in South England there occurred a passage from *A. granulatus* to *A. quadratus* synchronous with that which seems to be generally accepted as having taken place on the Continent and likely to be established for Yorkshire by Mr. Stather, the horizon at which that passage took place would appear to be pretty closely fixed by these specimens. (The specimen of *A. quadratus* recorded by me from this subzone in Hants[1] came, as far as I can judge, from a slightly higher horizon in the subzone.) I have found no other identifiable Belemnites in this subzone in Sussex.

In the subzone of abundant *O. pilula* in Sussex I have only found two Belemnites. One of them was found in the upper belt of *O. pilula*, but only the lower end is preserved. It is either *A. granulatus* or *A. quadratus*. The other specimen was found in the *Cinctus* belt; it had already been severely attacked at the upper end, but one side of the alveolar sheath still remained intact, and neither Mr. Crick nor Dr. Blackmore has any doubt as to its being *A. quadratus*. This agrees closely with Hants, where the only Belemnite known from this belt of the subzone is a fine specimen of *A. quadratus*, and where I have recently obtained a fairly certain specimen of that species from the lower belt of *O. pilula*.

In the zone of *A. quadratus* on the Sussex coast I have just obtained a specimen of *A. quadratus* about 8 feet above the zone of *O. pilula*, the first Belemnite I have yet seen in all the chalk of this zone that is accessible.

On the cognate subject of Ammonites, known to occur freely on this coast, it is worth noting that I have seen a great many, all of which were in the zone of *O. pilula*, and all but one in the subzone

[1] *The Stratigraphy of the Chalk of Hants*, p. 11.

of *E. scutatus*, var. *depressus*. The significance of this distribution is not necessarily very great, as specimens are only conspicuous on the foreshore and there is relatively little chalk of the subzone of abundant *O. pilula*, and hardly any of the zone of *A. quadratus* exposed on the foreshore.

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

REVIEWS.

I.—Earth Folds and Mountain Formation.

1. E. C. Abendanon. Die Grossfalten der Erdrinde. With a preface by Dr. K. Oestreich. pp. x, 183. Leiden, E. J. Brill; London, Dulau & Co.: 1914. £5.
2. K. Andrée. Über die Bedingungen der Gebirgsbildung. pp. viii, 101. Berlin, Gebrüder Borntraeger; London, Dulau & Co.: 1914. Marks 3 Pfg. 20.

THESE two works deal with special branches of geotectonic principles and they have many points in common. They show by the conclusions of their authors and by the extensive literature quoted—the references to which are by no means exhaustive—the steady growth of the belief that the main topographic features of the earth are due to movements of the crust and not to denudation. They both moreover agree in rejecting as a cause that great lateral thrusting to which, in many graphic passages, Suess attributed the behaviour of the land during the elevation of the fold-mountains of Eurasia. E. C. Abendanon, who is well known for his investigations in Mid-China and the Dutch East Indies, in his work discusses the 'Grossfalte' or the great folds of the earth.

'Grossfalte,' according to Abendanon, are broad uplifts due to the sinking of wider surrounding areas. He holds that all the main movements in the crust are vertical. The larger, heavier, stronger blocks sink and thereby force up the lighter, smaller, weaker blocks, which rise in flat swellings wherein the material expands and is under tension. 'Grossfalte' are therefore torn by disruption clefts and broken by rift-valleys, and overthrusting, due to the outward flow of the upraised material, occurs on the edges of these uplifted areas.

The book has a preface by Professor Oestreich, of Utrecht, who cautiously declines to predict whether the term 'Grossfalte' will become naturalized in science. Abendanon's thesis is that the formation of the major folds in the earth's crust is the most important of geological processes. These folds he attributes to vertical movements under the influence of gravity; he denies the great tangential thrusting assumed by Suess, and regards the main folding as caused by the crumpling of the crust during the shrinkage of the earth. The 'great folds' include the subsidence of the crust in geosynclines, its rise elsewhere in geanticlines, and also extensive systems of faults. In consequence of these movements the material of the geanticlines is cooled, and the rocks in them become hard and brittle; hence when disturbed the uplifted areas are torn by fractures. In the geosynclines, on the contrary, the material is heated and becomes plastic; hence when disturbed it yields by flowing, and, as the material below the geosyncline is compressed laterally while sinking, the hidden materials are intensely crumpled and altered. Fracturing is especially visible on the margins of the geanticlines, and as the central areas are lowered by denudation the anticlinals are exposed as metamorphic blocks. Amongst other consequences of this folding of the crust he includes the distribution of exposed metamorphic areas and former climatic changes; though he does not claim that it has been certainly proved that the glacial climate is due to anticlinal uplift, he believes "that it is the main factor and not improbably the only factor" (pp. 161–2).

In describing the special regions of 'Grossfalte' he begins with the Malay Archipelago; he claims that the movements there are independent of the pre-Tertiary structure. The movements began, he says, in the Neogene and were continued more briskly in the Pleistocene; they produced rift-valleys and sunklands as well as folds and were associated with powerful volcanic eruptions. Among European 'Grossfalten' he describes the rift-valley of the Rhine, the Pliocene dislocations of the Juras, the Pleistocene uplift of the Alps (proved by Penck for at least 400 metres), the pre-Glacial but young folding of Scandinavia, and the many important recent earth-movements in the Balkans and the Ægean. He favours the tectonic origin of Alpine lake-basins and attributes the long strike valleys of the Alps to tension clefts (Distraktionsrissen).

In America he describes the St. Lawrence as a recently foundered valley and more striking examples from Western America, where since the Quaternary there have been two great Falten. The eastern began in the Neogene and was enlarged in the Quaternary, while the western happened entirely in the Pleistocene. In Africa the Great Rift Valley and Madagascar supplies the author's chief examples. He therefore holds that all the continents have been greatly affected geographically by movements of recent age; although these disturbances are almost worldwide in distribution, he recognizes no regularity in their arrangement (p. 160). He attributes to them the determination of the main relief of the lithosphere, both submarine and terrestrial; and though he remarks that its genesis dates from the pre-Palæozoic, he holds that the present surface features of the earth are very young in age. Theories of the permanence of oceans and continents he apparently regards as unworthy of discussion.

Dr. K. Andrée, of Marburg, discusses the conditions of mountain formation. He belongs to the same school as Abendanon. His book is divided into three main sections; the first considers various theories of mountain formation, especially those dealing with the contraction and shrinking of the earth, the tetrahedral theory, the gliding theory of Reyer, and various thermal or expansion theories. He rejects the theories of the simple contraction and of tangential thrusting.

He objects to the original tetrahedral theory on the ground that radioactivity has rendered it uncertain whether the earth is growing cooler; but he quotes with approval the modification of the tetrahedral theory advanced in 1899. He regards with most favour the explanation that the great mountain chains are connected with geosynclinal subsidences and with the gliding of the adjacent areas under the influence of gravity. In the second part of his book, having cleared the ground by his preliminary discussions, he considers how mountains can be explained without invoking tangential pressure. He advocates the view that subcrustal flow is the main agency in mountain formation. This conclusion was advanced by Ampferer, and Dr. Andrée warmly supports it and discusses its relations to isostasy, the distribution of gravity, the structure and course of mountain chains, the distribution of the Atlantic and Pacific lavas, and the types of earthquakes classified as fracture-earthquakes and fold-earthquakes. In his third section he considers the evidence for the uplift of some areas into mountain chains at the present day, and refers especially to that suggestion in regard to the meridional ridge along the mid-Atlantic. He discusses the deep-sea material obtained by the German Antarctic Expedition and its discovery of continental sands on the floor of the South Atlantic, but he does not accept the view that the mid-Atlantic ridge has been proved to be a rising mountain chain. Like Abendanon he believes in the periodicity of movements in the earth's crust with an alternation of epeirogenetic and orogenetic movements.

Both books are valuable contributions to the study of the formation and distribution of the major features in the relief of the earth.

J. W. G.

II.—A Geological Map of the Caucasus. By Felix Oswald, D.Sc., B.A., F.G.S., F.R.G.S. With Explanatory Notes. London: Dulau & Co., Ltd., 1914. Price 15*s.* net.

Dr. FELIX OSWALD is already well known in the geological world by his treatise on *The Geology of Armenia*, published in 1906 (8vo, pp. ix, 516, with maps, plates, and sections), reviewed in the Geological Magazine, 1906, pp. 562–3.[1] The map now published has been compiled from the latest sources and is produced in colour on the scale of 1 : 1,000,000 or 15·78 miles to the inch. In the accompanying pamphlet of sixteen pages the author deals first with the general structure of the range, he then gives an account of its evolution, followed by an outline of the geological succession.

[1] In connexion with this map of Armenia it may be of interest to record that Sir Archibald Geikie, when President of the Geological Society of London, February 15, 1907, presented the "Murchison Geological Fund" to Dr. Felix Oswald (awarded to him by the Council), in recognition of the value of his contributions to our knowledge of the geology of Armenia in the remarkable volume then recently published. A further note on Dr. Oswald's work on the geology of Armenia will be found in the Geological Magazine for 1910, p. 283.

The chain of the Caucasus falls naturally into three main divisions: (1) the Central Caucasus, between Elburs and Kazbek; (2) the Western Caucasus, from Elburs westward to the point where the main axis runs into the Black Sea; (3) the Eastern Caucasus, from Kazbek to a point where the main axis runs into the Caspian. There are areas of Recent and Middle Tertiary beds (well-known to contain petroleum) at either end of the chain, which are characterized by the presence of mud-volcanoes. The western or Taman district lies in the north, while the eastern or Apsheron district lies to the south of the main axis.

The Central Caucasus is not only the loftiest part of the chain, but erosion has carved out such deep valleys that the structure is here most clearly revealed; its delimitation by Elburs (18,523 feet) and Kazbek (16,546 feet) is no arbitrary selection, but the natural expression of tectonic structure, for these volcanic masses lie on two transverse N.–S. fractures along which volcanic activity has been very pronounced, while they are still the seat of violent earthquakes.

The Western Caucasus becomes progressively simpler in structure, the core of gneiss and crystalline schists disappearing at Fisht beneath a cover of Jurassic and Cretaceous deposits; the main axis then diminishes rapidly in height, from over 9,000 to less than 3,000 feet, and consists for the last 200 miles of its course of only Upper Cretaceous strata.

The Eastern Caucasus, on the other hand, widens out to 140 miles in Daghestan. This district is essentially a succession of parallel chains in the south; but the northern part is a wide undulating plateau of Jurassic and Cretaceous beds.

The Daghestan plateau is broken off on the east by a nearly meridional line of fracture, a fall of 12,000 feet being thereby produced in a distance of only 10 miles. A fracture of similar magnitude parallel to the main axis delimits the Eastern Caucasus along its southern side, and at the point of intersection of these two great fractures the basalts and andesites of the Nial Dagh have been erupted, mineral springs occur, and earthquakes are frequent.

The account of the evolution of the Caucasus is of much interest. The main axis in the central division consists of gneiss, flanked by crystalline schists, which have been acutely folded into a geanticline displaying fan-structure, so that the schists dip beneath the gneiss and overlie in turn the reversed Palæozoic schists. The upraising of the Caucasus in the Permian period continued into the Trias,[1] excepting in the western division, which was partly covered by the waters connecting the Alpine sea with the Armenian and Indian seas. In the Lower and Middle Jurassic periods there was extensive submergence with oscillations allowing the local formation of coal. Intense folding again took place in the Upper Jurassic, with a Tithonian transgression on the north of the chain. The chief and

[1] In 1907 an important addition was made by the Russian geologist Mr. J. Worobiev to our knowledge of the geology of the Caucasus by the discovery of beds of Upper Triassic age on the Little Laba River at Psebai, and along the Khods River. Dr. Oswald gives an account of this in the GEOLOGICAL MAGAZINE for 1909, pp. 171–3.

latest period of folding took place after the deposition of the Middle Miocene (Sarmatian). The Central Caucasus was raised to its present height, its folds pinched in to become fan-folds, and the transverse fractures were developed on which Kazbek and Elburs built up their huge piles of lava.

The different formations are described and lists of their included fossils are given. The Quaternary and Recent deposits include Coast deposits of the Caspian up to 10 metres above the present level, Old Caspian and Black Sea deposits up to 26 metres, and the Aralo-Caspian Stage with terraces at 96 and 186 metres.

In the Pliocene the Pontian division contains gas in the Apsheron Peninsula. The Miocene and Oligocene beds yield much petroleum. The Cretaceous and Jurassic are well developed, and an outline is given of their stratigraphy. Basal conglomerates of the Jurassic lie unconformably on the eroded surface of the Palæozoic schists, of which they contain pebbles.

Triassic beds occur in the Western Caucasus, in the upper basins of the Bielaya and Little Laba Rivers, unconformably overlying Upper Carboniferous. The Palæozoic schists are probably in the main of Carboniferous age, though some may possibly be Silurian. A description is given of the main divisions of the igneous rocks which occur, and a note on the glaciers concludes the pamphlet.

Dr. Oswald's work is of the greatest value, and must form the basis of all future explorations in this most difficult but remarkably interesting country.

III.—Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1913. 8vo; pp. 107. Dulau & Co., 1914. Price 1*s.*

THIS number of the *Summary of Progress* shows the interesting nature of the work which has been accomplished during the past year and the large number of new and important facts which that work has brought to light.

The record of field-work is condensed into seventy pages. It is arranged as usual according to the different districts in which work has been prosecuted.

In England and Wales we find that in the Denbighshire district the surveying has been carried southwards into Shropshire, while the part of Cheshire included in the district has been completed and some further colliery information alone remains to be gathered in Flintshire. The Corwen-Glyn Grit has proved a valuable guide in disentangling the structure of the Ordovician rocks, but it has been found difficult to separate the Llandovery and Tarannon Beds, though the presence of both is proved by the graptolites. The examination of the Carboniferous Limestone escarpment south of Llangollen has been finished, and in Flintshire some sandstones hitherto regarded as Lower Coal-measures are now proved to be Millstone Grit. In Cheshire the survey of the peninsula of Wirral is now complete, and a commencement has been made on the deeply drift-covered Triassic area near Oswestry.

In the Warwickshire and Staffordshire district the mapping of the Etruria, Halesowen, and Keele groups has been continued south of Nuneaton, and a thin band of *Spirorbis* limestone known as the Index Bed, which occurs about 150 feet below the top of the Halesowen group, has been traced for a considerable distance. Above the Halesowen group there are upwards of 2,500 feet of sandstones with conglomerates and marls, and there is as yet no evidence to show whether any part of them can be assigned to the Permian. The Arden Sandstone group in the Keuper Marl has been traced for some distance, and the relation of the North Sea and Irish Sea drifts has been further investigated.

In the London and south-east district the surveying of the Chalk has progressed on both sides of the Thames, and the fauna of the horizon of *Heteroceras reussianum* has been proved to have a wide extent. The drifts and Tertiary beds have received much attention, and further light has been thrown, by the mapping, on the faults and folds which affect the strata underlying London.

In Scotland work has been carried on in the Highlands, principally in the counties of Sutherland, Ross, and Argyll. Further evidence of the former extension of the Middle Old Red Sandstone over the Northern Highlands has been obtained by the discovery of a considerable area of conglomerate and red grits 2 miles south of Loch Gaineamhach in Sutherlandshire. In North-Western Ayrshire the new base-line that has been adopted for the Lower Carboniferous is drawn above a series of reddish sandstones that are relegated to the Upper Old Red Sandstone, and revision of the original survey of the Carboniferous districts has also proceeded in the Paisley district and around Hamilton in Lanarkshire. It has proved possible to correlate the results of the geological mapping of the Carboniferous Limestone areas in Lanarkshire, Renfrewshire, and Ayrshire. Small patches of Jurassic rocks, in addition to those previously recorded, have been found in several places underlying the Tertiary lavas of Mull. It has been decided to make a more detailed investigation of the palæontological zones of the island of Raasay on account of the importance of the iron-ore deposits of that island. Here and in Skye an extensive deposit of oil-shale has been found which may prove to be of considerable economic importance. The mapping of the interior of Mull has been continued and has yielded interesting results.

During the year important petrographical and palæontological work has been carried out in connexion with the field-work in both England and Scotland.

Lists of additions to the museum and library are given. In the museum temporary exhibits have been arranged to illustrate the memoir on the geology of the Lizard district and the types of flint implements found at Swanscombe, Kent. There is also a list of maps and memoirs issued during the year. There are three appendices: (1) On the Heswall Boring, by Dr. Strahan; (2) On a Boring for Coal at Hemington, Somerset, by T. C. Cantrill and J. Pringle; and (3) Additional Notes on the Geology of the Lothian Shale-field, by R. G. Carruthers.

IV.—Diamonds in British Columbia.[1]

HITHERTO the only recorded occurrence of diamonds in their original matrix in North America has been that of Pike County, Arkansas, where they occurred in a peridotite. These were discovered in 1908, and during the following year 700 commercial diamonds were obtained. Considerable scientific interest therefore attaches to the discovery, by Mr. R. A. A. Johnston, mineralogist to the Canadian Survey, of small diamonds in chromite segregations in the peridotite of Olivine Mountain in the Tulameen district. The peridotite of Tulameen shows on analysis close similarity with the diamond-bearing peridotite of Arkansas, and both are closely related to the 'kimberlite' of South Africa. The diamonds occur as small octahedra associated with the chromite, towards which they are idiomorphic; and as small spherical patches of a yellowish colour, apparently consisting of aggregates of small particles occurring in veinlets in the chromite. The largest individuals obtained are described as about the size of an ordinary pin's head, but in many cases these individuals break up into small particles within a few hours of being freed from their matrix. Hitherto no diamonds have been found in the gold-placers of the district. It appears clear that the chromite which always accompanies the diamonds is an original constituent, and crystallized later than the octahedral diamonds. The peridotite is intrusive through a series of rocks containing little or no carbonaceous matter, so that it is probable that the carbon existed as an original constituent of the magma.

V.—Canada.

DEPARTMENT of Mines. From the Mines Branch we have received: the Annual Report on the Mineral Production of Canada for 1912, Preliminary Report on the Mineral Production of Canada for 1913 and a paper on the "Preparation of Metallic Cobalt by the Reduction of the Oxide", by H. T. Kalmus and others (1913). The latter publication forms part i of the researches on cobalt and cobalt alloys conducted at Queen's University, Kingston, Ontario, for the Mines Branch.

From the Geological Survey Branch we have Memoirs 23, 25, 26, 30, 37, and 44, with the accompanying maps.

Memoir 23. *Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound, British Columbia.* By J. A. Bancroft. pp. 146, with 6 figures in the text, 17 plates, and 1 map. 1913.—Although this is to be regarded as a preliminary report, it contains much material of great scientific interest. Those interested in physical geology will find many valuable observations on fiords and hanging-valleys, with a discussion of their origin. The petrography of the igneous rocks of the Coast Range and of the regional and contact metamorphism of the stratified rocks is treated in detail. The plutonic rocks occur in the form of large batholiths. These have been dissected to considerable depths by the fiords, and the

[1] *Geology and Mineral Deposits of the Tulameen District, British Columbia.* By Charles Camsell. Canada, Department of Mines, Geological Survey, Memoir No. 26, pp. 146–53.

sections afford many opportunities for discussing the methods by which the overlying strata are invaded. The phenomena observed are found to corroborate the theory of "overhead stoping" advanced by Daly.

Memoir 25. *Report on the Clay and Shale Deposits of the Western Provinces.* By A. Ries and J. Keele. pp. 99, with 6 figures in the text and 40 plates. 1913.—The first report on this subject was published as Memoir 24 E. The present memoir is devoted almost entirely to technical detail; it shows the extension of several useful types of clay discussed in the earlier publication.

Memoir 26. *Geology and Mineral Deposits of the Tulameen District, British Columbia.* By C. Camsell. pp. 188, with 2 figures in the text, 23 plates, and 4 maps. 1913.—This memoir contains some interesting petrography dealing with igneous rocks of Jurassic and of Tertiary age, one notable point being the discovery that the Otter granite, a large batholithic mass, is of post-Oligocene age. The occurrence of platinum in this district has been discussed by Professor J. F. Kemp, whose results have been confirmed by recent observations. The most valuable scientific discovery is that of diamonds occurring in chromite segregations in a peridotite. This is discussed more fully in a separate brief notice above (see p. 375).

Memoir 30. *The Basins of Nelson and Churchill Rivers.* By W. McInnes. pp. 146, with 19 plates. 1913.—The area dealt with in this memoir lies between the Saskatchewan River and Hudson Bay, a district which has been traversed by traders and explorers since 1697. Part of the region was explored by Sir John Franklin's first expedition in 1819–21. The memoir embodies the work of several officers of the Geological Survey between 1877 and 1910. The general geology deals with the early pre-Cambrian rocks, which form the central complex of the region, and with the overlying sedimentary beds, which range from Upper Huronian to Upper Cretaceous. Detailed descriptions are given of the rivers and lakes. Large areas are covered by lacustrine clays belonging to the age of the declining glaciers, some of these occupying an extension of the glacial Lake Agassiz described by Upham in 1888.

Memoir 37. *Portions of the Atlin District, British Columbia.* By D. D. Cairnes.—This is the subject of an earlier notice in this journal (1914, p. 129).

Memoir 44. *Clay and Shale Deposits of New Brunswick.* By J. Keele. pp. 94, with 7 figures in the text, 16 plates, and 1 map. 1914.—In addition to much useful technical information this memoir contains a brief discussion of the origin of clays and shales which will serve as a useful introduction to those interested in the subject.

VI.—Geological Literature added to the Geological Society's Library during the year ended December 31, 1912. 8vo; pp. 268. London: Geological Society, 1914. Price 2*s*.

THIS invaluable publication has now reached its nineteenth year. It is somewhat late, owing to the change of Librarians and consequent dislocation of business entailed, and it is more bulky owing to omissions in the last volume necessarily made up in this. Several improvements have been made, notably in the attempt to give bibliographic exactness to authors' names and in having a more definite plan in the Index. It is not too much to say that the publication reflects the highest credit on the new Librarian, Mr. C. P. Chatwin. Few people realize the incredible labour it is for one man to compile such a book, with the pressing duties of a library and its visitors to contend with, even when assisted by a competent junior, and we must all feel profoundly thankful that in this volume we recognize that the most valuable publication of the Geological Society of London has entered on a new lease of life with renewed vigour. It is by far the best Record of Geological Literature that is published, and is as useful to the amateur as to the professional.

VII.—Brief Notices.

1. The Crust of the Earth.—The crust of the earth comes in for a good deal of study in the *Journal of Geology*, vol. xxii, No. 2, 1914. W. H. Hobbs continues his papers on the mechanics of formation of Arcuate Mountains, Joseph Barrell continues his on the strength of the earth's crust by writing on "The Regional Distribution of Isostatic Compensation", and T. C. Chamberlin continues the diastrophism and the formative processes by "The Testimony of the Deep-sea Deposits". Important preliminary results of measurements of the Rigidity of the Earth are contributed by A. A. Michelson. The first and last papers are well illustrated and can be easily followed.

2. Lancashire and Cheshire.—The Proceedings of the Liverpool Geological Society, vol. xi (4), 1913, contain papers of markedly local interest. Excavations at Liverpool and Birkenhead have been watched and recorded by C. B. Travis and T. A. Jones, and plants and other remains are recorded from Seaforth. W. T. Walker writes on the Boulder-clay of North Wirral, and H. C. Beasley describes the Storeton find of 1912 and reproduces Morton's map of the faults in the Storeton area. Numerous references occur throughout to the variety of rocks found in the Lancashire-Cheshire Boulder-clay, but we do not remember any special paper dealing with the subject which would probably be worth working up.

3. Chalk of Suffolk.—Mr. P. G. H. Boswell has given a sketch of the Chalk of Suffolk in the Journ. Ipswich Field Club, vol. iv, 1913. He records the successive zones from that of *Belemnitella mucronata* to *Holaster planus*, and although he does not give a list of his fossils, the few he quotes are sufficiently convincing. The thickness of Eocene beds to the east and south of the county may hinder the publication of a zonal sketch-map of the county, but Mr. Boswell's paper is based on field work and personal observation and will be a sufficient guide to any one familiar with the Chalk and its fauna, especially when read in conjunction with his paper "On the Age of the Suffolk Valleys" issued in vol. lxix of the Quarterly Journal of the Geological Society, 1913 (1914).

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

June 18, 1914.—Sir William Crookes, O.M., President, in the Chair.

Among other papers read was the following:—

"A Description of the Skull and Skeleton of a peculiarly modified Rupicaprine Antelope, *Myotragus balearicus* (Bate)." By Dr. C. W. Andrews, F.R.S.

Myotragus balearicus (Bate) is a peculiarly modified rupicaprine antelope, remains of which were discovered by Miss D. M. A. Bate in cavern deposits in Majorca and Minorca (see *ante*, pp. 337–45).

The dentition is very remarkable. Instead of having three incisors and a canine on each side of the mandibular symphysis as is usual in the Bovidæ, the canines and the two outer pairs of incisors are wanting, while the median incisors are enormously enlarged rodent-like teeth, growing from persistent pulps. The premolars are reduced in number and the molars have very high crowns.

The feet are remarkable for the shortness and stoutness of the metacarpals and metatarsals, which are quite similar to those of the Takin (Budorcas). The animal seems to have been adapted for climbing on steep crags and cliffs, and probably lived on very hard vegetation. A full account of the osteology and dentition is given in the paper.

II.—Geological Society of London.

June 10, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communication was read:—

"The Ballachulish Fold near the Head of Loch Creran (Argyllshire)." By Edward Battersby Bailey, B.A., F.G.S.

The district of Lower Glen Creran has recently been much more carefully examined than heretofore. The course of the Ballachulish Fold had already been determined with approximate accuracy. The purpose of the present paper is to draw attention to two phenomena strikingly illustrated by the local evidence:—

(1) The complexity of the slides affecting the Ballachulish Core, and the correlated (quite exceptional) occurrence of more groups towards the close of the fold, south-east of the River Creran, than towards the gape, north-west of the same.

(2) The intense secondary refolding of the Ballachulish Fold, and the resultant sinuous outcrop of the Ballachulish Core.

Dr. Douglas Mawson gave an account of the geology and glaciation of the Antarctic regions, as observed in his recent expedition, and exhibited a series of magnificent lantern-slides, many of which reproduced the natural colouring by direct photography. A unanimous vote of thanks, proposed by the President and seconded by Dr. J. J. H. Teall, was tendered to Dr. Mawson, by whom it was briefly acknowledged.

June 24, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Paradoxidian Fauna of a part of the Stockingford Shales." By Vincent Charles Illing, B.A., F.G.S.

This communication deals mainly with a small subdivision of the Stockingford Shales occurring at the base of the Oldbury division. The beds have been termed the Abbey Shales, and are about 100 feet thick, consisting mainly of blue laminated shales, although glauconitic sandy horizons occur at frequent intervals. This small subdivision passes down into the Purley Shales, while it is separated from the overlying shales (which are probably of Lower Maentwrog age) by a calcareous conglomerate lying upon an eroded surface of the underlying blue shales, although the irregularity of the eroded surface does not appear to be great in the somewhat poor exposures.

The beds have been examined in a series of trenches situated near the Abbey Mound in Hartshill Hayes, and have yielded over fifty different species of Trilobites—each ranging through one or more of about fifteen fossiliferous horizons in the sequence. The fauna shows marked affinities with those of the equivalent beds in Wales, Scandinavia, and Bohemia, and the following subdivision into zones has been attempted:—

Horizon.	
G 3–G 1	Upper *davidis* fauna.
F 3–F 1	Lower *davidis* fauna.
E 3–E 1 (*pars*)	*Hartshillia* fauna.
E 1 (*pars*)–D 1	Upper *hicksii* fauna.
C 3–B 1	Lower *hicksii* fauna.
A 4–A 1	*P. aurora* fauna.

The importance of the Abbey Shales lies in the possibility which they afford of a close correlation between the Swedish and British Paradoxidian faunas, for the intermediate geographical position is accompanied by an intermediate type of fauna forming a link between these two well-known areas.

The following is a brief summary of the correlation which appears to agree best with the available evidence:—

SOUTH WALES.	HARTSHILL.	SCANDINAVIA.	
P. davidis zone.	Upper *P. davidis* fauna.		
	Lower *P. davidis* fauna.	*P. davidis* zone.	
	Hartshillia inflata fauna.	*Ct. æqualis* subzone.	*P. tessini* zone.
P. hicksii zone.	Upper *hicksii* fauna.		
	Lower *hicksii* fauna.	*Agnostus parvifrons* subzone.	
P. aurora zone.	*P. aurora*-zone.	*Ct. exsulans* subzone (*pars*).	

In addition, the evidence suggests that the Upper Purley Shales correspond to the rest of the *Ct. exsulans* zone and also the *P. ölandicus* zones of Sweden.

The Abbey Shales appear to have been deposited in rather a shallow sea, in which slight changes in conditions introduced marked variations in the rock-types. Corresponding to these alternating physical conditions there occur alternations of faunas—a good example being afforded by *Agnostus rex*, found in the coarse shales, and *A.* (*Ct.*) *intermedius*, found in the blue shale.

Towards the close of the Middle Cambrian Period excessive shallowing of the water introduced a period of marine erosion—causing a break in the sedimentary sequence with the elimination of the equivalents of the *P. forchhammeri* zone, and in some cases a portion of the *P. davidis* zone. This break appears to have extended over a large part of Great Britain. Attention is drawn to the fact that none of the characteristic forms which occur exclusively in the rich *P. forchhammeri* zone of Scandinavia have been noted from any locality in Great Britain.

2. "The Trilobite Fauna of the Middle Cambrian of the St. Tudwal's Peninsula (Carnarvonshire)." By Tressilian Charles Nicholas, B.A., F.G.S.

In a previous paper on the geology of the St. Tudwal's Peninsula approximate determinations were given of the fossils found in the Upper Caered Mudstones and Nant-pig Mudstones, both of Middle Cambrian age. The object of the present paper is to give detailed descriptions of several forms which are either new or of particular interest: namely, *Agnostus kjerulfi*, two new species of *Agnostus*, a species of *Agraulos*, of *Dorypyge*, of *Corynexochus*, and *Solenopleura applanata*, and to give brief notes on a number of other species, including *Agnostus punctuosus*, *A. exaratus*, *A. fissus*, *A. altus*, *A. truncatus*, *Microdiscus punctatus*, *Conocoryphe* cf. *dalmani*, and *Paradoxides hicksii*.

The vertical distribution of the different forms through the Upper Caered and Nant-pig Mudstones is tabulated and compared with that of other areas, particularly the succession recently established by Mr. V. C. Illing in the Abbey Shales of Nuneaton. This comparison strengthens the opinion already put forward in the previous communication, that there is a non-sequence at the base of the *Lingula* Flags in the St. Tudwal's Peninsula.

III.—Mineralogical Society.

June 16, 1914.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Dr. J. Drugman: Childrenite from Crinnis Mine, Cornwall, and Eosphorite from Poland, Maine. Analysis of childrenite from Crinnis Mine showed it to contain even less manganese than the specimens from George and Charlotte Mine. Eosphorite from Poland is richer in manganese than that from Branchville, the only occurrence previously known. It is well crystallized, unlike the Crinnis Mine childrenite. — R. H. Solly: On Sartorite. From a geometrical examination of 200 crystals it is concluded that Dr. Trechmann's crystals, Nos. 1 and 2, belong to a new species closely allied to sartorite and smithite. Many new forms for sartorite were found.—

Dr. G. T. Prior: Re-determination of Nickel in the Baroti and Wittekrantz Meteorites. Precipitation with ammonia was found not to separate iron from nickel completely, however often the operation was repeated. Re-determination showed that the proportion of iron to nickel in the case of both the meteorites in question was nearer 6 : 1 than 10 : 1 as previously stated.—Dr. L. L. Fermor: Ice Crystals from Switzerland. Last winter the surface of the snow in shady situations near Zweisimmen and Lenk was often characterized by a dense growth of hollow prisms formed of a thin shell of ice coiled spirally parallel to the face of a hexagonal prism.—Dr. L. L. Fermor: Hematite from the Kallidongri Manganese Mine, India. The crystals, which had the habit of corundum and were marked with three sets of striations due to twin lamellation parallel to 100, showed the forms 111 and $61\bar{4}$ well developed, together with 100, $22\bar{1}$, 28. 28. 13 (a new rhombohedron), $51\bar{3}$, $71\bar{5}$, and $10\bar{1}$ less prominent.—H. B. Cronshaw: A variety of Epidote from the Sudan. A mineral discovered by Mr. G. W. Grabham in a pegmatite vein closely resembles allanite in appearance, but is free from rare earths and agrees in composition with epidote; in its pleochroism and negative sign it also resembles the latter, but has an abnormally low optic-axial angle of about 54 degrees. In thin section it represents a well-marked zonal structure.

CORRESPONDENCE.

SATURATION OF MINERALS AND GENESIS OF IGNEOUS ROCKS.

Sir,—The separation of the different mineral components of an igneous rock is so complex a question that it requires a careful study of each individual rock type, with every effort to follow the different vicissitudes to which it has been subjected from its original state of a homogeneous, vitreous paste, through its magmatic differentiation till its final cooling, not to speak of subsequent changes. In the vast majority of somewhat ancient rocks that are only exposed by erosion the time occupied by this may represent very considerable changes subsequent to complete consolidation.

I fully agree with Mr. A. Scott[1] in his protest against the classification of rocks independent of their 'cooling history', or, to put it more correctly, he agrees with me! The American classification of rocks I look upon as many steps backwards by this introduction of a cumbersome nomenclature and diagrams, interesting perhaps to the chemists, but murderous to the true naturalist or geologist. It hides the beautiful forms of geological phenomena under a gaudy patchwork mantle of mostly untenable hypotheses spangled with fantastical names. I say that Mr. A. Scott agrees with me, for, if he will consult the papers quoted below,[2] he will find himself forestalled in

[1] See Geol. Mag., July, 1914, pp. 319–24.

[2] "Geology of Vesuvius and Monte Somma": Q.J.G.S., vol. xl, pp. 35–119, 1884. "Some Speculations on the Phenomena suggested by a Geological Study of Vesuvius and Monte Somma": Geol. Mag., Dec. III, Vol. II,

many facts marshalled by him in his discussion of Professor Shand's paper in the GEOLOGICAL MAGAZINE.[1]

It is for nearly thirty years now that I have been preaching the same sermon—the 'cooling history' or, as I prefer to call it, the 'vicissitudes of consolidation', which I may sum up under the following heads:—

1. Primary composition of the paste.

2. Additions, or rather acquisitions, to it in its progress from its source to its final position: (*a*) assimilation of materials from its enclosing rock, (*b*) materials brought to it with the assimilation of saline solutions, gases, etc., otherwise *endosmotic* metamorphism.

3. Losses from it in its progress from its source to its final position: (*a*) abandonment of materials to its enclosing rock, (*b*) losses of soluble materials to fluids circulating in its vicinity, or losses of volatile constituents escaping by pores, fissures, or a chimney opening to the atmosphere, etc., otherwise *exosmotic* metamorphism.

4. Rate of cooling or interruptions of cooling: (*a*) to surrounding rocks, (*b*) loss in the acquisition of H_2O or other materials, volatile or otherwise, (*c*) conduction by surrounding rocks, (*d*) evolution of volatile materials, (*e*) vesiculation, or the conversion of volatile materials from the volume of a liquid dissolved in a liquid to the state of a gas, (*f*) ebullition and sublimation of volatile materials by fumaroles or an open volcanic vent.

5. Diminution, rapid or slow, and other vicissitudes of pressure.

I was able to show that, of the sister minerals, orthoclase was formed under high pressure, whilst leucite was individualized under low pressure and principally at an open volcanic vent, as exhibited by the large crystals of leucite growing over big plates of sanidine. The same was shown with regard to amphibole and augite. Furthermore, the presence of small quantities of some bodies that have been called mineralizers, but may well be called catalyzers, may be added to my list of 'vicissitudes of consolidation'.

What determines, for instance, in low-pressure minerals, the final separation of the three felspathoids, leucite, haüyne, or nosean, all of which appear in almost identical conditions in the lavas of Monte Vultura and other localities? Why do abyssal minerals, such as amphibole, sommite, biotite, and, I can lately add, garnet, be deposited under practically no pressure in the loose pipernoid tuffs of the Campania? I have specimens of bones of *Cervus elaphus* (which I have described) covered with crystals of amphibole and a nepheline mineral (sommite or micro-sommite) and biotite, which must have been deposited at so low a temperature that even now the gelatinous constituent of these bones has not been carbonized, but, by heating over a flame, can be blackened yet covered, as such specimens

pp. 302–7, 1885. "The Relationship of the Structure of Igneous Rocks to the Conditions of their Formation": Sci. Proc. R. Dublin Soc., N.S., vol. v, pp. 112–56, 1886; see also Q.J.G.S., vol. xli, pp. 103–6. "On the Fragmentary Ejecta of Volcanoes": Proc. Geol. Assoc., vol. ix, pp. 421–32. "The Causes of Variation in the Composition of Igneous Rocks": Nat. Sci., vol. iv, pp. 134–40, 1894.

[1] See paper by Professor S. J. Shand in GEOL. MAG. for 1913, pp. 508–14.

are, by a crust of these silicates.[1] In this case there is no doubt that fluorides contained in the tuff magma were the catalyzers or mineralizers.

When we have solved all these problems, then will be the time to institute a true classification of rocks and their mineral constituents, but until then any of the recent attempts to do so only hide our ignorance under a cloud of fantastic but unfounded generalizations. The 'saturation of minerals' is, I contend, more accurately represented by my 'principle of fraction exhaustion'.

H. J. Johnston-Lavis.

Vittel (Vosges), France.
July 16, 1914.

OBITUARY.

Rev. OSMOND FISHER, M.A., F.G.S.,

Hon. Fellow and late Tutor of Jesus College, Cambridge.

Born November 17, 1817. Died July 12, 1914.

So lately as last June we claimed our dear and valued friend, the Rev. Osmond Fisher, as one of the four surviving contributors to the opening volume of the Geological Magazine in 1864, and now in August we have to record his loss. He passed peacefully away on Sunday, July 12, after an honourable and useful life of 97 years, retaining his faculties active until the end.

Those who *knew* him need no record of his worth; for the younger generation of geologists, we may refer them to his life and portrait which appeared in the Geological Magazine for February, 1900, pp. 49–54.

From a very early age Osmond Fisher displayed a keen interest in geology, and was an assiduous collector of fossils in Dorset and Wilts. When at King's College he attended lectures by Lyell and Daniell and visited the galleries of the British Museum. He entered Jesus College, Cambridge, in 1836, taking up mathematics, in which he graduated as 18th Wrangler in 1841. Whilst at Cambridge Fisher attended Sedgwick's lectures and soon a warm friendship followed, and later on, in 1852, Sedgwick proposed Fisher as a Fellow of the Geological Society.

Besides the numerous papers which Osmond Fisher communicated to the Geological Society, the Philosophical and the Geological Magazines, the British Association, and elsewhere, he published a most important work, *The Physics of the Earth's Crust*, to which subject he devoted fully thirty years of his life, and expended the best efforts of his mathematical powers to perfect.

The Geological Society, always anxious to welcome the contributions of mathematical geologists, awarded him the 'Lyell Fund' in 1887, and the Murchison Medal in 1893; but the crowning recognition of his life's work, the award of the Wollaston Gold Medal, did not take place until 1913, probably owing to the retirement in

[1] "On the Formation at Low Temperatures of certain Fluorides, Silicates, Oxides, etc., in the Pipernoid Tuff of the Campania": Geol. Mag., Dec. IV, Vol. II, pp. 309–13, 1895.

which Mr. Fisher remained for so many of his latter years, and to the vast number of younger geologists occupying the stage, amongst whom this illustrious early worker was for a time overlooked.

Mr. Fisher was elected an Honorary Fellow of King's College, London, in 1878, and of Jesus College, Cambridge, in 1893. His portrait was subsequently painted and placed in the Hall of Jesus College.

SIR JOHN BENJAMIN STONE, KNT.,

J.P., F.S.A., F.G.S., M.P. FOR EAST BIRMINGHAM 1895–1909, HIGH STEWARD OF SUTTON COLDFIELD.

BORN FEBRUARY 9, 1838. DIED JULY 2, 1914.

ALTHOUGH most widely known and recognized as the "Prince of Photographers", and during fourteen years as Conservative M.P. for East Birmingham, Sir Benjamin Stone was remarkable as a tireless traveller, having visited Japan, China, British Columbia, Vancouver and the Rocky Mountains, the West Indies, the River Amazon, the Straits Settlements, Asia Minor, Europe generally, and Egypt specially.

He was an accomplished antiquary and enriched the places he visited by his remarkable photographic records. He wrote accounts of his travels in Japan, Brazil, Spain, and Norway, and made the photographic history of the Houses of Parliament, of Westminster Abbey, the Tower, Windsor Castle, St. James's Palace, Lichfield Cathedral, and Sutton Coldfield, of which last place he was five times Mayor and was the founder of its celebrated Vesey Club.

Some years since Sir Benjamin Stone commenced to photograph the most interesting objects preserved in the British Museum (Natural History), Cromwell Road. One of these, representing the complete skeleton of *Diprotodon australis* (reconstructed in part from remains in the Natural History Museum, but chiefly from skeletons discovered by Dr. E. C. Stirling, F.R.S., at Lake Callebonna, South Australia), forms the subject of Plate XV in the GEOLOGICAL MAGAZINE, Dec. V, Vol. VI, pp. 337–9, August, 1907, in illustration of an article by Dr. Arthur Smith Woodward, F.R.S. Among his geological photographs is one taken of Mount Vesuvius during an eruption, when stones were being hurled into the air and lava flowed nearly at his feet.

It is earnestly to be desired that the magnificent series of portraits he took of his many eminent contemporaries, and of the thousand and one places which he visited—commencing in 1868—should find a suitable resting-place in the British Museum or other national repository.

Sir Benjamin Stone was not only celebrated as a photographer; he will long be remembered as one of the most amiable and generous of men, who spared no pains nor private means to promote the welfare of all those with whom he was brought into contact, and his numberless acts of kindness have endeared him to a very wide circle of devoted friends who lament his loss. Lady Stone, his constant companion in his travels, only survived her husband three days.

All Communications for this Magazine should be addressed to

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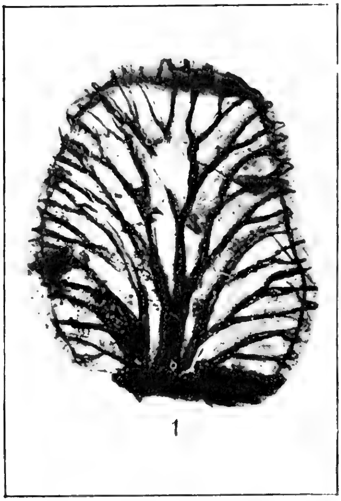

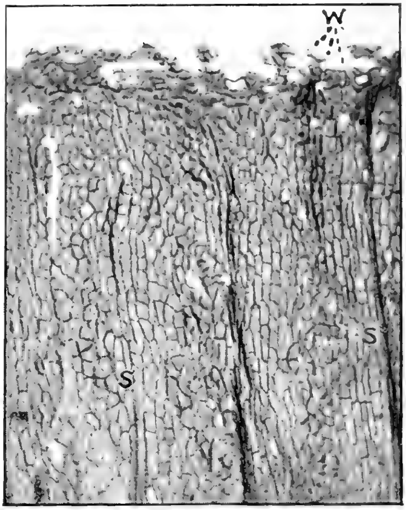

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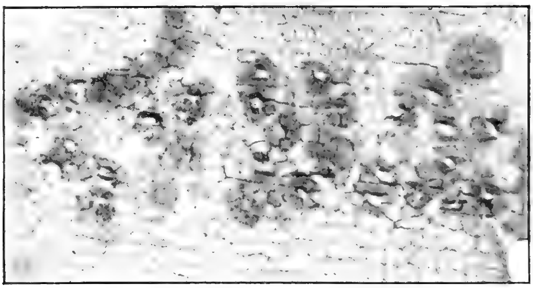

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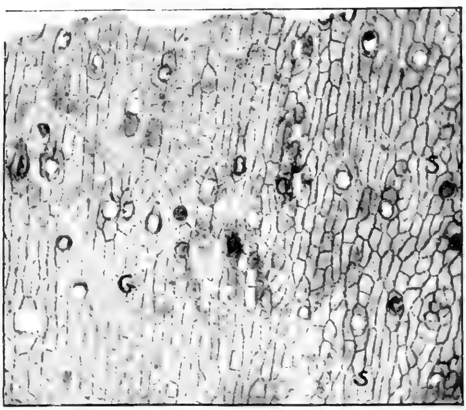

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O. T. Elliott & W. Tams phot.

Plant-cuticles from British Coal-measures.

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

No. IX.—SEPTEMBER, 1914.

ORIGINAL ARTICLES.

I.—Plant Cuticles from the Coal-measures of Britain.

By Lucy Wills.

(PLATES XXX AND XXXI.)

1. Introduction.

OUR knowledge of the structure of the cuticle of Coal-measure plants is very meagre in comparison with the amount of information recently published as to the cuticular characters of Mesozoic genera. So far as I know, no detailed descriptions have been published of the cuticles of British Palæozoic plants. Professor Zeiller[1] has described a few cuticles of French Carboniferous plants, and Dr. Huth[2] recently gave an account of the cuticle of *Mariopteris muricata*, but very little has so far been attempted in this branch of research. The present preliminary account deals with material obtained by Mr. L. J. Wills from the Middle Coal-measures of the Denbighshire Coal-field near Chirk and from the Old Hill Marls (Etruria Marls?) in the Upper Coal-measures of South Staffordshire. The cuticles are preserved as brown films in clayey shales, approaching fireclays in composition, none having yet been found in carbonaceous or sandy shales. It is hoped that this note will incite collectors to search for further specimens in this state of preservation.

The chief interest of the discovery of actual plant cuticles is that they afford a new weapon with which to attack the palæobotanical problems of the Coal-measures. The fact that different parts of the plant are preserved in this way may lead, on further investigation, to a correlation of these parts and to the identification of detached fragments. I have been unable in the time available to examine in any detail the spores and seeds collected, but I have made preparations of both macrospores and microspores from the cones of different species of *Lepidostrobus* and of platyspermic seeds of the *Cordaites* type and others of unknown affinity. I hope in the future to investigate these more fully.

The following account records briefly the results obtained from an examination of the leaf cuticles of several different species.

2. Method of Preparation.

The methods of preparation employed are those which have yielded much valuable information as to the cuticular structure in many Mesozoic forms.[3] The cuticles were soaked off the shale, treated with

[1] R. Zeiller, *Houille et Perm d'Autun et d'Epinac*, p. 115.

[2] W. Huth, *Palæobot. Zeitsch.*, Bd. i, pp. 7–14, 1912.

[3] For details of this method see A. G. Nathorst, *Palæobot. Zeitsch.*, Bd. i, p. 26, 1912, and H. H. Thomas and N. Bancroft, Trans. Linn. Soc., vol. viii, pt. v, p. 157.

Schülze's macerating fluid, and then washed in ammonia. The bleached cuticle alone remains after this treatment. The two surfaces of the leaf when present were separated by careful teazing with needles. The preparations were stained with either Bismarck brown or diamant fuschin.

3. Description.

Neuropteris heterophylla, Brongn.

Localities: Preesgwyn and near Cefn. Horizon: Middle Coal-measures.

The general form and venation of the leaflets are indicated in Pl. XXX, Fig. 1. Under the microscope the leaflets show two distinct types of cuticular structure; both types possess the following common features. The cells of both the upper and lower epidermis are roughly polygonal in outline, except over the vein-courses, where they are rectangular and elongated in the direction of the venation. The cell-walls are of a normal thickness and straight. On one surface the stomata are fairly numerous, approximately sixty-eight to the square millimetre, while on the other there are only a few scattered ones. On both surfaces they are restricted to the areas between the vein-courses.

The stomata (Pl. XXX, Figs. 2, 3, 4, 5, *S*) are irregularly arranged. Each individual one (Text-fig. 1) is nearly spherical in shape. The guard-cells are slightly sunk, lightly cuticularized, and sometimes imperfectly preserved. The cells surrounding the stomatal cavity, generally five or six in number, are similar to the other epidermal cells, but take a deeper stain; where they abut on to the stomatal cavity they form a solid ring of thickening (Pl. XXX, Fig. 4).

The distinguishing feature between the two types is the presence of small papillate hairs on one surface of the leaf in type β and their absence in type a. As there are corresponding types of *Cyclopteris* leaflets (*Cyclopteris* is a name given to one type of *Neuropteris* foliage), it would seem possible that two distinct species of *Neuropteris* are here represented. Further, in a few specimens of type a a marginal zone of water-stomata occurs (Pl. XXX, Fig. 2, *W*). This is of interest, as the same structure is found in the corresponding *Cyclopteris* type (Pl. XXXI, Fig. 7) and in some modern forms.[1] These stomata are similar in structure to the ordinary air-stomata but larger, more circular in outline, and with a less prominent ring of thickening round the stomatal cavity (Pl. XXX, Fig. 2; Pl. XXXI, Fig. 7). Certain of these stomata have a thin walled tissue in the stomatal cavity in place of the normal two guard-cells.

In addition to the two types described two specimens show glandular patches on certain cells of the single surface preserved (Pl. XXX, Fig. 5). These glandular cells, like the hairs in type β, are irregularly scattered over the whole leaf surface. No water-stomata have been observed in this type.

Leaflets of a *Neuropteris* have been collected from the Old Hill Marls, but have not yet been identified.

[1] G. Haberlaudt, *Physiologische Pflanzenanatomie*, 1909, p. 449.

Cyclopteris sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures.

Specimens examined show two types of epidermal structure similar to those described for *Neuropteris heterophylla*.

The form and venation of the leaflet is shown in Text-fig. 2. In several specimens both surfaces of the leaf were preserved and were separated; Pl. XXXI, Figs. 6, 7, represent the two surfaces of one fragment. The form and arrangement of the cells and stomata are illustrated on Pl. XXXI, Figs. 6, 7, and Text-fig. 3. Their close similarity to type *a* of *Neuropteris heterophylla* can be clearly seen by comparing these figures with Pl. XXX, Figs. 2, 5, and Text-fig. 1.

STOMATA AND GUARD-CELLS.

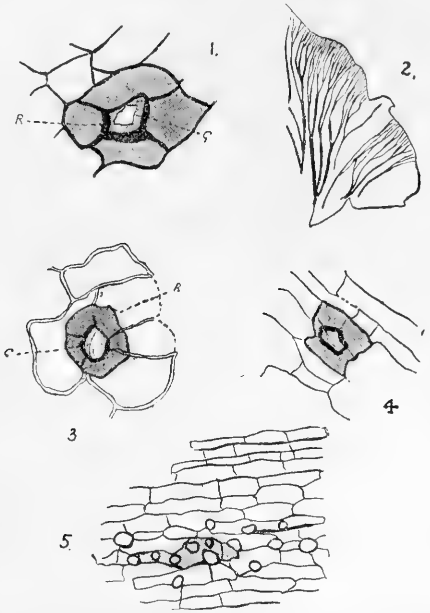

FIG. 1. *Neuropteris heterophylla*. *R*, ring of thickening; *G*, guard-cells.
,, 2. Half of a *Cyclopteris* leaflet.
,, 3. *Cyclopteris* sp. *R*, ring of thickening; *G*, guard-cells.
,, 4. *Cordaites* sp.
,, 5. *Cordaites* sp.

Water-stomata similar to those already described form a continuous band round the edge of that leaf surface which carries the numerous stomata.

Type *β*. The specimens classed under this heading are similar to those of type *a* in form, but are frequently not lobed. The one surface is slightly hairy and imperfectly preserved; the other shows cells of a normal structure and a few scattered stomata. Water-stomata have not been observed.

Alethopteris sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures.

Both surfaces are preserved, but could not be separated. As in the two species already described the cells over the vein-courses are rectangular and elongated in the direction of the veins, those in the intervening areas polygonal.

The stomata can only be observed on one surface; they are fairly numerous, approximately eighteen to the square millimetre, and arranged in rows parallel to and between the vein-courses as shown on Pl. XXXI, Fig. 9. In structure the stomata are of the same type as in *Neuropteris heterophylla.* The guard-cells can be clearly seen in the stomatal cavity. The whole structure is similar to that described by Professor Zeiller for *Alethopteris grandini*, except that in the present case the guard-cells are also preserved. They are illustrated on Plate XXXI, Fig. 10.

Pecopteris sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures.

Only one epidermal surface is preserved in this species. The cells are polygonal except over the vein-courses, where they are rectangular and elongated in the direction of the veins. No stomata have been observed in the specimens examined.

Cordaites sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures. Locality: Old Hill, S. Staffs. Horizon: Upper Coal-measures.

Preparations from several species have been made, all of which show the same cuticular structure. The two surfaces are preserved, but the one epidermis does not make good microscopic preparations; it shows, however, thin-walled cells and rows of stomata between the vein-courses. The other surface is well preserved. The cells are thick-walled, rectangular, and elongated in the direction of the vein-courses; those immediately above these being narrower and longer than those in the intervening areas (see Pl. XXXI, Fig. 11). There are a few stomata on this surface; they are oval in shape and arranged in rows parallel to the venation. The stomata are smaller than in the forms described above, and are frequently surrounded by four cells which form a ring of thickening round the cavity (Text-fig. 4). The guard-cells are lightly cuticularized and frequently imperfectly preserved. Circular structures of unknown significance occur at irregular intervals on the well-preserved surface (Text-fig. 5).

Thalloid growth.

Locality: Old Hill. Horizon: Upper Coal-measures.

A thalloid growth of uncertain affinity covers certain layers in the Old Hill Marls. A typical piece is figured on Pl. XXXI, Fig. 8. At first sight it appears to be formed of cutin, but since it dissolves in Schülze macerating solution it must be of a different chemical composition.

The fragments found measure as much as 10 mm. in length and average 1·5 mm. in breadth. They branch dichotomously and repeatedly. This fact, together with the lack of differentiation of

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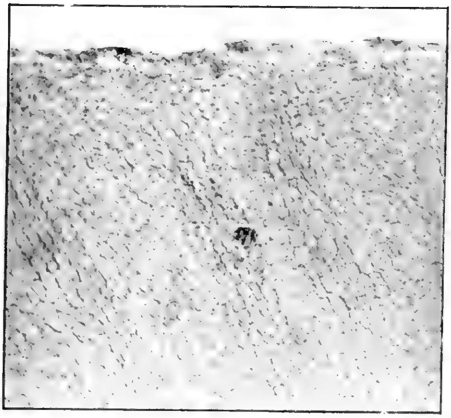

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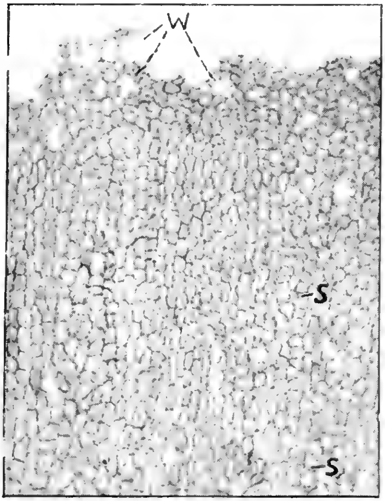

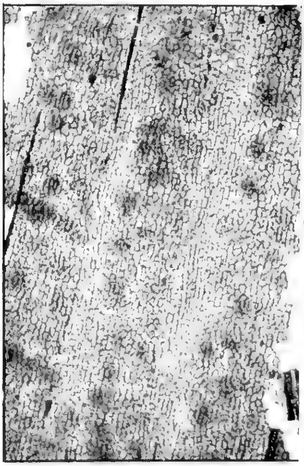

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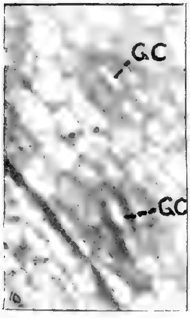

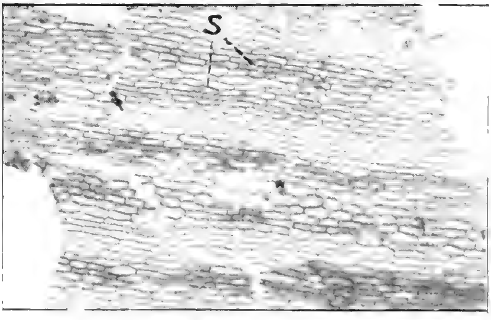

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O. T. Elliott & W. Tams phot.

Plant-cuticles from British Coal-measures.

the tissue and the presence of spore-tetrads embedded in the thallus, points to the possibility of its being a primitive type of Bryophyte. Should further study support this view, these specimens will be of great interest as being the first Bryophytes recorded from the Palæozoic rocks.

4. Conclusions.

1. *Morphological.*—The chief interest in a study of the structure of a leaf cuticle centres round the stomata. In the specimens described above one type of stoma is common to all the species. The type is simple. A girdle of subsidiary cells surrounds the stomatal cavity, forming a ring of thickening where they abut on to it. The two guard-cells are slightly sunk in the stomatal cavity. The prevalence of this simple uniform type of stoma is of interest, since the cuticles examined by Professor Zeiller and Dr. Huth respectively showed distinct differences of stomatal structures, and in the case of *Alethopteris* the structure observed was interpreted differently by the two observers. Professor Zeiller [1] concluded that the guard-cells, which were missing in his specimen, were originally present but had not been preserved. Dr. Huth,[2] however, maintains that in all probability the guard-cells were never present, and that stomata were of an aquatic type similar to those in *Mariopteris muricata.* The description of the stomata of *Alethopteris* given above entirely bears out Zeiller's contention, but it is hoped that a further study will throw more light on this structural point.

2. *Ecological.*—The discovery of cuticular remains in the Coal-measures is of importance ecologically, since the epidermal features of a plant, especially the arrangement, structure, and number of the stomata, are intimately related to climate and habitat. Yet results based on the cursory examination of a few species can be of little value, and I do not propose to do more than make a few tentative suggestions. Dr. Huth has already suggested that the aquatic type of stoma found in *Mariopteris muricata* indicates an extremely humid atmosphere. The different types of cuticular structure found in *Neuropteris heterophylla* and *Cyclopteris* would seem to lend support to this view, for such authorities as Warming [3] and Haberlaudt [4] cite water-pores, glandular patches, and hairs on the epidermis as characteristics of plants living under humid conditions. If we assume that these structures functioned as hydathodes it is probable that the hairs and glandular patches occurred on the lower surface of the leaf and the water-stomata on the upper. If this be so, the stomata are more numerous on the upper surface, a feature which is consistent with the view that the plants were hygrophytic. Yet the number of stomata is less than might have been expected under such circumstances.

3. *Phylogenetic.*—It is possible that the structure of the stomata may eventually prove of use in tracing the phylogeny of modern forms. Suggestive in this respect is the similarity between the

[1] R. Zeiller, op. cit.
[2] W. Huth, op. cit.
[3] E. Warming, *Ecology of Plants*, English trans., 1909, p. 101.
[4] G. Haberlaudt, op. cit., pp. 445, 451.

stomata in these Palæozoic types and those of certain Cycads described by Messrs. Thomas and Bancroft.[1]

In conclusion I would like to express my gratitude to Professor A. C. Seward for many valuable suggestions and criticisms, and to Mr. Hamshaw Thomas, of Downing College, Cambridge, who gave me numerous useful hints on the methods of preparing and mounting the cuticles. I wish also to thank my brother, Mr. L. J. Wills, for very kindly placing the material at my service and for his encouragement during this research.

EXPLANATION OF PLATES.

PLATE XXX.

FIG. 1. *Neuropteris heterophylla*, Brongn. Leaflet. × about 4.
,, 2. ,, ,, Stomata *S*, water-stomata *W*. × 50.
,, 3. ,, ,, Group of stomata. × 50.
,, 4. ,, ,, Stomata. × about 167.
,, 5. ,, ,, Glandular patches *G*, stomata *S*. × 50.

PLATE XXXI.

FIGS. 6, 7. *Cyclopteris* sp. Type *a*. Two surfaces of same leaflet. Stomata *S*, water-stomata *W*. × 50.
FIG. 8. The cuticle of a dichotomously branched thalloid structure. × 17.
,, 9. *Alethopteris* sp., showing rows of stomata. × about 24.
,, 10. *Alethopteris* sp., stomata, guard-cells *G.C.* × about 167.
,, 11. *Cordaites* sp., stomata *S*. × 50.

The Text-figures are all camera-lucida drawings of the actual specimens.

II.—A New Trilobite from the Millstone Grit of North Yorkshire.

By W. B. R. King, B.A., F.G.S.

(PLATE XXXII.)

THE highest beds of the Carboniferous rocks of Wensleydale are found on the summit of Great Shunner Fell, which is situated on the watershed between Wensleydale and Swaledale, and forms the high ground to the west of the Buttertub Pass on the road between Hawes and Muker.

At a point 650 yards south-west of the Currack of Great Shunner Fell, called Shunner Fell Well on the 6 in. to a mile ordnance map (Yorkshire, Sheet L), a thin band of limestone and calcareous shale is seen forming a conspicuous feature. A detailed section of the beds exposed at this locality shows about 12 feet of calcareous beds. The limestone in question is described in the Geological Survey memoir on *The Geology of the Country around Mallerstang, etc.*, where the following description of the Millstone Grit of that area is given "The overlying bed is a very thick shale, which forms the greater part of Shunner Fell. In it there are two thin bands of fossiliferous limestone, which are to be seen near Shunner Fell Well on the west side of the hill. In one of these Mr. Goodchild found a trilobite. A tiny outlier of grit forms the extreme top of Great Shunner Fell." [2]

[1] H. H. Thomas and N. Bancroft, op. cit., pp. 155–204.
[2] *The Geology of the Country around Mallerstang, etc.* (Mem. Geol. Surv.), 1891, p. 145.

The limestone bed is a little over 500 feet above the base of the Millstone Grit as defined in the above-mentioned memoir.[1] Mr. J. Pringle has kindly identified the fossils from these beds, and has drawn up the following list:—

Athyrid.
Chonetes laguessiana, de Kon.
Ch. sp. (papilionaceous var.).
Lingula squamiformis, Phill.
Martinia glaber (Mart.).
Productus cf. *longispinus*, J. Sow.
P. sp. (*semireticulatus* group).
Schizophoria resupinata (Mart.).
Spirifer bisulcatus, J. de C. Sow.
S. sp.
Posidoniella lævis (Brown).
Pseudamusium fibrillosum (Salter).
Glyphioceras bilingue (?) (Salter).
Orthoceras sp.
Cladodus mirabilis (?), Ag. (tooth).

These specimens are now in the Jermyn Street Museum, the registration numbers being Z 333–74.

Mr. R. G. Carruthers has sliced several Corals, which were obtained from the highest limestone bed, and has identified *Zaphrentis costata* and *Z. constricta*; the latter, he remarks, occurs normally in the Lower Limestone group of Scotland.

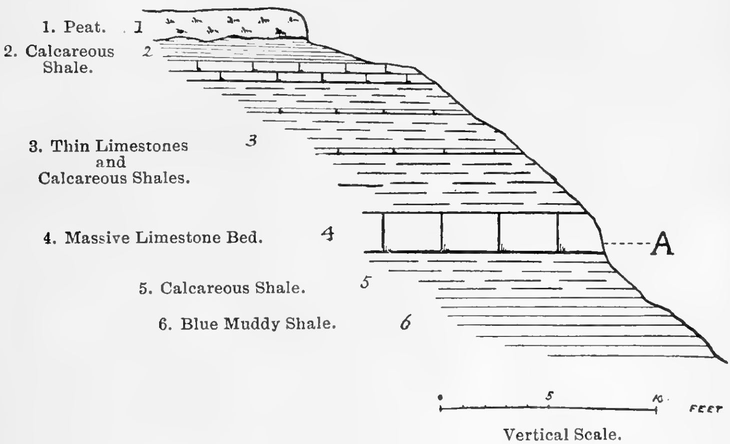


FIG. 1.—Section at Great Shunner Fell Well, Yorkshire.

A list of fossils, chiefly only with the generic names, is given in the Geological Survey memoir,[2] but the specimens are not preserved in the Survey collection.

The Millstone Grit underlying the calcareous beds of this area, although mainly comprised of grits and sandstones, and containing the Tan Hill coal and other thin seams, is essentially a marine formation, since many of the grits contain casts of *Spirifer* and Crinoids. The strata were evidently formed rapidly in a sinking area, and the change in character of the beds, resulting in calcareous deposits, may be due to failure in the supply of coarse material, aided by an increased depression of the area. As a result of this change to clearer

[1] *The Geology of the Country around Mallerstang, etc.*, 1891, pp. 11–12.
[2] Ibid., p. 160.

water conditions, there was a migration of more open water forms into the area.

The calcareous beds are probably on the same horizon as the Botany Beds of the Middleton in Teesdale district, the fauna of which Professor Garwood considers to be "the highest truly marine fauna yet met with in the North of England".[1] Although the fauna of the Shunner Fell Beds is in many respects unlike that of the Botany Beds, the want of similarity is probably due to a difference in the conditions of the sea at the time of deposition, rather than to any great difference in age. The presence of a well-marked marine horizon high up in the Millstone Grit on this area is of interest, as it tends to support Professor Garwood's view that the fauna of the Botany Beds migrated from the south-west or west.

The Trilobites are found throughout the calcareous beds, but are best preserved in one of the more massive limestone beds, marked A in the section (Fig. 1). They are found in many stages of growth, but appear to belong to one species. At first sight they resemble *Phillipsia Eichwaldi* (Fischer), but on close examination they are found to be a species of *Griffithides*. It would seem that this is one of the highest horizons at which Trilobites are found in England, and the forms might be expected to be somewhat modified. The specimens have been shown to Dr. H. Woodward, and he considers them to belong to a new species. As they are particularly well preserved and many complete specimens have been found, there is ample material from which to describe the species.

GRIFFITHIDES SHUNNERENSIS, nov. sp. (Plate XXXII.)

General outline, elliptical.

The measurements of an almost perfect specimen give the following results:—

Total length	2·15 cm.
Greatest breadth	1·03 ,,
Length of head	·7 ,,
Length of thorax	·55 ,,
Length of pygidium	·9 ,,

Head semi-oval, nearly as long as broad.

Glabella inflated, pear-shaped, expanded anteriorly, narrowing posteriorly, where it is elevated. The surface (when the original shell is preserved) is ornamented with fine granules; these are relatively larger in the young stages. When the shell is removed the surface appears perfectly smooth, although a few specimens show two slight undulations, which may mark the position of degenerate glabella furrows.

The basal lobes are well defined, triangular, and smooth.

The neck furrow is deep and curves in its central portion towards the glabella. The neck ring is broad and swollen, and is ornamented with one central tubercle and small granules, which are larger and more distinct on the posterior margin.

The fixed cheeks are narrow, with well-marked raised lobes at the eyes. The free cheeks have a small smooth raised portion, but the

[1] E. J. Garwood, Quart. Journ. Geol. Soc., vol. lxviii, p. 543, 1912.

surrounding border is broad, and ornamented by fine ribs, which run parallel to the margin. The cheeks are produced posteriorly to form conspicuous flattened spines, which reach to the sixth thoracic segment.

The eyes are three-tenths the length of the glabella; they are finely facetted and reniform.

Most of the specimens, when the original shell is preserved, show two depressions, one on either side of the glabella, above the eye-lobe.

Thorax consists of nine segments. The axis is slightly tapering, and is rather less than one-third of the total width of the thorax. It is ornamented with a single row of fine granules along the posterior border. The pleuræ are grooved and end rather squarely, although the anterior angle is slightly rounded, and the posterior angle is produced to form a very short blunt spine.

Pygidium semi-ovate in outline. Central axis elevated and tapering, but ending bluntly. It is composed of sixteen fused segments. The lateral lobes are ten in number. The axis is ornamented in the same manner as the thoracic axis. The lateral lobes are smooth. The pygidium is completely surrounded by a broad, slightly curved border, the margin is entire.

Hypostome similar to that of *Phillipsia Eichwaldi*,[1] length two-thirds that of the glabella. Upper border curved anteriorly. The oblong raised central portion is parallel-sided, and ornamented by small pits. There are two posteriorly directed oblique furrows on the lower parts of this raised portion. The wings are broadest in the upper portions, where their breadth is equal to the total length. From the place of greatest breadth they narrow rapidly towards the centre of the hypostome and then follow the raised axis; their lower portion is well developed, and ends bluntly with rounded angles. The surface of the wings is finely ridged; these ridges are specially well-developed in the broader parts. (See Plate XXXII, Fig. 3.)

This species, although in many respects similar to *Phillipsia Eichwaldi* (Fischer), differs from it, firstly, in having no well-marked glabella furrows; secondly, the lobe over the eye is much more developed in the Shunner Fell species; and thirdly, the pygidium is of a slightly different outline.

The only species of *Griffithides* with genal spines of similar proportions is *G. longispinus* (Portl.). The whole shape of this species is quite different. *G. acanthiceps* (H. Woodward) is of similar appearance, but its pygidium has only thirteen segments. The figures of *G. calcaratus* (McCoy) are not good enough to identify a specimen from; moreover, its glabella is said to be smooth.

Many theories have been advanced as to the use of the 'pores' on the glabella of Trilobites. The subject is discussed by Dr. Woodward in an appendix to his work on the Carboniferous Trilobites in the Memoirs of the Palæontographical Society.[2]

The following are among the suggestions which have been put forward: that they were points of attachment of external antennæ;

[1] H. Woodward, *Carboniferous Trilobites* (Palæont. Soc.), pl. iv, fig. 4.
[2] Ibid., 1884, pp. 71–6.

that they were the places where the muscles working the hypostome were attached; or that they were ocelli. Moreover, the different authors do not agree as to whether they were perforations in the shell, or merely depressions.

It may not be out of place here to add a few notes on these 'pores' as exhibited in the above-described species. The pores are situated just in front of the eye-lobe, on the furrow separating the glabella from the fixed cheek. The surface of the shell immediately surrounding the depression is smoother than the rest of the glabella. In well-preserved specimens the depressions appear as deep oval pits in the shell, with their longer axes parallel to the length of the glabella. When observed from the under side the shell is seen to be bent downwards to form a slightly hollowed cone. A section through the pore shows that the shell is not perforated, but rather thickened on the margins of the cone, while the inside of the cone is flattish and rough. The shell forming the rim and inner portion of the cone seems, however, to be of a different nature to the rest of the glabella, being somewhat lighter in colour. This lighter portion also forms the base of the upper funnel-shaped depression (Fig. 2).

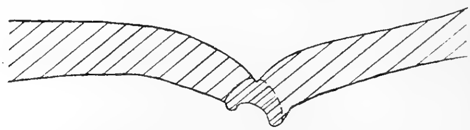


FIG. 2.—Section through pore just in front of the eye-lobe on the furrow which separates the glabella from the fixed cheek.

The function of these pores is difficult to decide; but the rough surface of the under side of the cone suggests a place of muscle attachment; if this be so, it would agree with M. Barrande's contention, but against this there is the difference in the ornamentation of the upper surface and the change in the character of the shell, which would seem to indicate the presence of some sense organ.

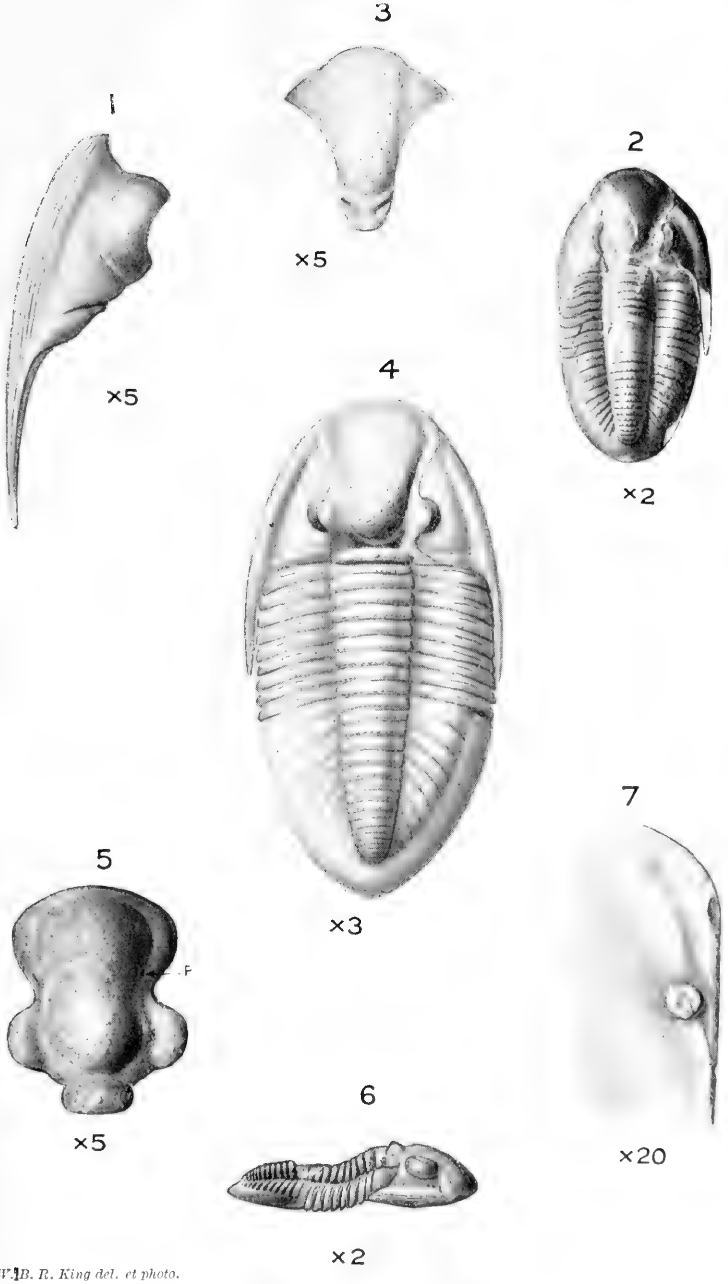
In conclusion I have to thank Professor T. McK. Hughes and Dr. H. Woodward for much help in working out the Trilobites, and Dr. J. E. Marr, at whose suggestion I first visited Shunner Fell. I have also to thank Messrs. A. W. R. Don and H. T. Kennedy, of Trinity College, Cambridge, and Mr. R. Hodgson, of Hawes Junction, for helping me to collect the specimens.

EXPLANATION OF PLATE XXXII.

FIG. 1. Free cheek and eye, showing facettes. × 5.
,, 2. Almost complete specimen. × 2.
,, 3. Restoration of hypostome. × 5.
,, 4. Restoration. × 3.
,, 5. Glabella of young specimen showing granulated surface and large lobes. *P.* position of 'pore'. × 5.
,, 6. Side view of almost complete specimen. × 2.
,, 7. 'Pore' seen from the under side. × 20.

Figs. 1, 2, 5, 6, 7 are photographs.

Note.—These specimens are now in the Sedgwick Museum, Cambridge.



W. B. R. King del. et photo.

Griffithides Shunnerensis, King, sp. nov.

III.—The *Cheirotherium.*

By D. M. S. Watson, M.Sc., Lecturer in Vertebrate Palæontology in University College, London.

ALTHOUGH educated Europeans have never carried the art of 'spooring', or tracking, to the perfection with which it is employed by the Australian and African natives, it is possible for us by applying a little common sense and certain experience of the tracks of living beasts to the fossil footprints so commonly found in terrestrial deposits laid down under arid conditions to find out many features of the animals which made them.

The tracks of *Cheirotherium* are commonly found in the Trias of Britain and Germany. They occur in the Bunter and the lower part of the Keuper, the faunas of which rocks are still very imperfectly known in Europe. The most marked features of a Cheirotheroid track are—

1. That there are impressions of all four feet.
2. That the fore-feet are very much smaller than the hind.
3. That the hind-feet are always the more deeply impressed.
4. That the track is extremely narrow, the feet of the two sides being planted nearly on the same line.
5. That the stride is long.

1. Shows that the animal was four-footed.
2. That the fore-legs were feeble in proportion to the hind.
3. That the animal was very nearly balanced about its pelvis.

There are two ways in which such a balance can be arrived at; either the beast stands bolt upright like a meer-kat (*Suricata*) or a man, or it has a tail as long and massive as its body. The fact that *Cheirotherium* habitually touched the ground with its fore-feet shows that it must have adopted the latter method and have had a large massive tail.

The fact that the track is very narrow shows that *Cheirotherium* was a very good walker; any animal which has a wide track, like a tortoise, has to swing from side to side whilst it is walking in order to keep its centre of gravity over its track, and in doing so wastes a large amount of muscular energy. Every animal which carries its feet so close together that its track is nearly a single line must have special arrangements to prevent it from kicking itself when running, and is consequently likely to have well-ossified and 'finished' limb-bones. An animal with a narrow track must, if it is to be efficient, have a pelvis which is very narrow between the acetabula compared with the length of its limb-bones; if it be otherwise, then, when the animal is viewed from the front, the femur will not be in a vertical plane, the animal being 'knock-kneed', a position which keeps the abductors constantly in strain. *Cheirotherium* was thus a four-footed animal with relatively small fore-legs and long heavy tail and narrow pelvis. The very considerable stride, about a metre in the case of the commonest British species, shows that it was at least as long in the leg as a man.

The groups of animals known, by the discovery of their bones, to have been in existence in Europe during the time of the *Cheirotherium* are—

1. The Stereospondylous Stegocephalia. The limbs of these amphibia are extremely imperfectly known, but the materials of *Mastodonsaurus* and *Metoposaurus* show that, like all the Permian Stegocephalia, they had very short legs, the humerus and femur being carried at right angles to the body and the track necessarily very wide. The apparent rarity of caudal vertebræ suggests that the tail

FIG. 1.—Footprints of *Cheirotherium.*

was short. Furthermore, it is rendered probable by the enormous size of the head, which must have carried the centre of gravity very far forward, that the fore-feet were larger than the hind.[1] They can therefore have had nothing to do with *Cheirotherium.*

[1] The Stuttgart material of *Mastodonsaurus*, when examined in the light of the now well-known *Eryops*, shows clearly that Dr. Fraas's familiar restoration of the pelvis is quite wrong; his 'ilium', as shown conclusively by the occurrence of a specimen lacking the pubis, and of an isolated ischium, is really the whole os innominatum, nearly identical with that of *Eryops.* Dr. Fraas's pubis is an ischium, and his ischium a scapula-coracoid extremely similar to that of *Eryops.* There is also a humerus, figured by Pleininger many years ago, which, except that it is rather more slender, perfectly resembles that of *Eryops.*

The few Cotylosaurian reptiles known from the European Trias are all very small lizard-like animals, and as all known members of this group have a very wide track they could not have been the makers of the *Cheirotherium* footprints. The limbs of the remarkable primitive Phytosaurian from the Bunter of Bernberg described by Jaekel as *Palæorhinus* are quite unknown, but there is every reason for believing that they resembled those of the later form *Mystriosaurus*, which is shown by MacGregor's description of an American form, and generally resemble those of modern crocodiles in proportions; these animals of course make a quite different type of track to *Cheirotherium*.

Other important Triassic groups are the Tortoises, which make an extremely characteristic spoor, with the feet of opposite sides widely separated, and each individual print very short from back to front, with the impressions of claws standing clear of the sole.

2. *Hyperodapedon*, the track of which must have been like that of a heavily built lizard.

3. The Lizards themselves, which make a sprawling track, are of course quite out of the question.

As *Cheirotherium* tracks are always found in terrestrial deposits, and even in rocks which we have reason for believing were laid down under arid conditions, it is unnecessary to discuss the marine groups of the Ichthyosauria, Sauropterygia, and Placodontia. The only remaining groups are the lightly built Thecodonts, of which *Aetosaurus* and *Ornithosuchus* are the best-known members, and the Dinosaurs. These groups differ only slightly in structure, and it is almost certain that the latter is derived from the former. The differences lie almost entirely in the limbs. The fact that the proximal tarsals of the Thecodonts are not rigidly articulated to the tibia and fibula suggests that the whole foot was placed on the ground as in a lizard. The whole structure of the hind-leg suggests that it was carried in a somewhat lizard-like manner with the femur at a considerable angle with the body and the various sections of the leg considerably flexed. This opinion is supported by the fact that the acetabulum is imperforate, and also by the actual position of the legs in the type-specimens of *Aetosaurus*, in which the animals still, to a large extent, retain the form they had during life.

There remain only the Dinosaurs, which in the known Triassic forms seem to have been generally bipedal, and resemble *Cheirotherium* in having long heavy tails, so that the animal is balanced about the pelvis, in the small size of their fore-legs, in the narrowness of the pelvis, in the length of the leg, and in the narrowness of their track. There can, in fact, be no doubt that *Cheirotherium* was a Dinosaur or direct Dinosaur ancestor.

It remains to compare the actual footprints with known Dinosaurian feet. The excellent work of Lull on the American tridactylous footprints from the Trias of Connecticut, which he has successfully correlated with the lightly built carnivorous forms, such as *Anchisaurus*, shows that we must look elsewhere for *Cheirotherium*. The typical lightly impressed print of a Cheirotheroid pes has five digits, of which the third is the longest and the fifth is turned outward and backward. The first and second toes often show traces of distinct pads, there being two on the first and three on the second digit. It is obvious, from inspection of good prints, that these pads lie below the articulations, as in Dr. Lull's Dinosaurs, and not between them as in ourselves. The distal end of each digit ends in a small claw, which extends beyond the pad. The posterior ends of the pads of the toes are separated when lightly impressed and represent the articulation between the lower ends of the metatarsals and the first phalanges.

The sudden termination of the pads behind shows that the metacarpus was carried clear of the ground, i.e. that the animal was digitigrade. In some exceptional specimens the pads run into a distinct sole, as is, for example, the case in the type-specimen of *Cheirotherium herculis*; in such cases, which may represent a resting position, the 'heel', which is presumably made by the metacarpus, is slightly longer than the phalangeal part of the impression. The

FIG. 2.—Restoration of *Plateosaurus* from specimens in the Berlin Museum. After an outline figure by Professor Jaekel, in *Die Woche*, Hft. xxvi, Berlin, 1912.[1]

fifth digit, which we have not hitherto considered, lies in an extremely curious position with its very large posterior pad behind the third digit. The whole arrangement suggests that the metatarsal acted as a sort of strut to the tarsus, the other four metatarsals standing not quite vertically, but at some angle between that and horizontally. It is, unfortunately, impossible to determine the number of phalanges in this toe, but it is not improbable that there were only two. No known Triassic Dinosaur has so well-developed a fifth toe as *Cheirotherium*, but the foot of *Plateosaurus* seems to me not very dissimilar, and it is quite possibly a descendant of that animal. The further reduction of the fifth digit in most Dinosaurs may conceivably be due to the fact that when the metatarsus became vertical its use as a strut disappeared, and, as no other use for it presented itself, it was rapidly aborted.

[1] [This Text-figure, from the *Guide to Friar Park, Henley-on-Thames* (1914), p. 27, fig. 12, was kindly lent by Sir Frank Crisp, Bart. (The scales have been added, and are not in Professor Jaekel's outline figure.)—ED. GEOL. MAG.]

IV.—On the Triassic and Permian Rocks of Moray.

By D. M. S. Watson, M.Sc., and G. Hickling, D.Sc.

Some time ago one of us [9] showed that the 'New Red Sandstone' rocks of Morayshire may be divided into three groups, two of which are of Permian age and the other Triassic. The recent very rapid increase in our knowledge of Permian and Triassic reptilian faunas allows of a closer correlation than was attempted in the former paper.

To the fauna of the Trias two new types have been added from the Lossiemouth quarries, viz. *Brachyrhinodon Taylori*, v. Huene [5], a Rhynchocephalian, and *Saltopus Elginensis*, v. Huene [4], which is said to be a Dinosaur. None of the Triassic species, except *Hyperodapedon Gordoni*, is known from any other locality, so that there is little direct evidence of their age, but Professor v. Huene, whose experience of Triassic faunas is unrivalled, believes them to be of the same age as the Lettenkohle [6], a determination which may be provisionally accepted.

Whatever the precise horizon, the absence of Labyrinthodonts is remarkable (it now seems certain that *Dasygnathus* does not belong to that group), but is probably to be explained by the prevalence of desert conditions. All the species known from Elgin appear to be dry-land types.

No new types have recently been added to the Permian group from Cuttie's Hillock Quarry. The species there present are *Gordonia Juddiana*, E. T. Newton, and four other species; *Geikia Elginense*, E. T. Newton; *Elginia mirabilis*, E. T. Newton.

Gordonia is a typical '*Dicynodon*' and agrees very closely with certain specimens of that genus from the *Cisticephalus* zone of the Karoo, of Upper Permian age.

Geikia is a more interesting and unusual type. It is not closely paralleled by any other known form, but is simply derived from *Dicynodon* by the development of horns on the nasals. Among the types in the *Cisticephalus* zone of South Africa a similar tendency is observable, though in a less degree, in the development of slight thickenings or even distinct knobs, which may be regarded as 'rectigradations' of the *Geikia* horns. The *Cisticephalus* zone is the equivalent of the *Pariasaurus* beds of the Russian Dwyna, which are shown by the occurrence of marine fossils to be Upper Permian.

Elginia is related to *Pariasaurus* as is *Geikia* to *Gordonia*. Its great spinosity is a very advanced character. The typical Pariasaurians of the *Pariasaurus* zone of South Africa are only moderately ornamented with bosses and scutes. Those from the higher *Cisticephalus* zone (e.g. *Propappus*) show a much greater development of dermal armour and a further increase in spinosity. Judging from Professor Amalitzski's photographs, the types from the equivalent Upper Permian horizon of Russia are also very much ornamented and much covered with scutes, although none are known to be so spinous as *Elginia*, which represents the acme of spinosity in this group. The undetermined sacrum from Elgin figured by Newton is undoubtedly Pariasaurian and almost certainly belongs to *Elginia*. This specimen also indicates a very advanced type, from the loss of the intercentra between the lumbar vertebræ which are preserved.

The indications of these three reptiles as to the age of the Cuttie's Hillock Beds is therefore very clear and consistent, viz. that they are slightly younger than the Upper Permian Pariasaurian beds of Russia or the *Cisticephalus* zone of South Africa; being thus at the extreme top of the Permian or about the Permo-Triassic boundary. A feature of great general interest is that by their occurrence in these rocks these three reptiles are shown to be dry-land or even desert animals.

The Cummingstone Beds have still only yielded footprints. Some time ago one of us showed that these impressions belong to the same types as those at Mansfield, Dumfries, Penrith, and Exeter, two forms being common to Mansfield and Cummingstone [2, 3]. A further examination of the material in the Elgin Museum, and of numerous imperfect tracks in the Cummingstone quarries, completely

FIG. 1.—*Chelichnus* sp. × ½. This footprint agrees exactly in form with those figured (but not named) by Huxley as the smaller impressions from Cummingstone (Huxley, *The Crocodilia of the Elgin Sandstones*: Mem. Geol. Surv., Monograph iii, 1877, pl. xv, figs. 1–4, pl. xvi). It differs in being twice as large. The photograph shows two associated natural casts in relief. The upper one represents a deep impression, showing the characteristic crescentic mound of sand in the rear. The lower one is a lighter impression, without the mound, but showing the claw markings well. This type of footprint is much the most common throughout the Upper Permian of Britain. Locality: 300 yards W.N.W. of 'Elginia' Quarry, Cuttie's Hillock, Elgin.

confirms this identification. The occurrence of the Mansfield tracks in the Magnesian Limestone definitely fixes their age as Upper Permian (Zechstein) [8], a determination supported by the widely distinct character of the vertebrate tracks known from the Lower Permian (Rothliegende) of Thuringia [7] and Hampstead [1]. The Cummingstone Beds must, therefore, be of nearly the same age as the Cuttie's Hillock Elginia deposits. That such is actually the case is conclusively shown by our fortunate discovery of one of the typical Cummingstone footprints in a quarry distant only 300 yards W.N.W. from the Cuttie's Hillock reptile quarry (see Fig. 1). The evidence of the footprints and the reptiles is thus mutually confirmatory of the Upper Permian age of these rocks.[1]

Mode of Origin of the Deposits.—The Permian and Trias are typical 'red rocks' in this area, of the same general type throughout. They are yellow and white sandstones and conglomerates, strongly false-bedded; they contain scattered pebbles in lenticular patches, rarely forming regular conglomerates; the fossils are distributed in the same irregular manner, never in regular beds. These are emphatically the characteristics of terrestrial, not of aqueous deposits, and we would suggest that throughout this great interval the district was continuously a land-surface, on which all these deposits gathered as drifting sand. In this way we may understand why an apparently quite thin series of rocks represents so great an interval of time, and yet no visible unconformity has ever been found. The Permian and Triassic reptiles all appear to have been terrestrial, except perhaps *Hyperodapedon* and *Stenometopon*, which may have been river forms.

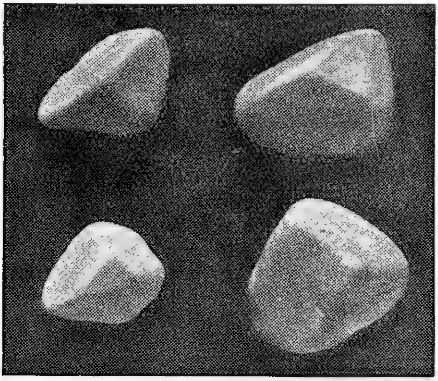


FIG. 2.—Dreikanter from the Upper Permian of Cuttie's Hillock Elgin, 200 yards north-east of 'Elginia' Quarry.

The emphatically 'desert' character of the Permian in the 'Dreikanter' quarry of Cuttie's Hillock has been previously described and is here illustrated by a better photograph of some of the typical dreikanter (Fig. 2). Finally, we may suggest that the curious 'cherty rock' in the Trias at Stotfield, Lossiemouth, finds its nearest modern parallel in the superficial chalcedony which develops over the sands in certain dry sandy regions such as the Fayum.

[1] It may be observed that one of the tracks from Dumfries among the Jardine Collection in the Edinburgh Museum (middle slab in Cases 1 and 2) appears to be specifically identical with Huxley's *Chelichnus megacheirus* from Elgin. The pair of slabs at the top of Case 8 in the same collection may represent the species here figured from Cuttie's Hillock. Possibly also the very large prints from Cummingstone figured by Huxley (of which several good examples are preserved in the Elgin Museum) may be Jardine's *Chelichnus titan*, but the preservation of the latter is too imperfect for close comparison.

Summary.—(1) The reptiles *Gordonia*, *Geikia*, and *Elginia* are shown to be slightly later than those of the Upper Permian *Pariasaurus* beds of Russia, or those of the equivalent *Cisticephalus* zone of South Africa. They therefore represent the extreme top of the Permian. (2) The remaining Elgin reptiles are Middle Triassic (? = Lettenkohle of Germany). (3) The Elgin footprints are widely distinct from Triassic forms and from those of the Lower Permian, while agreeing exactly with the group associated with the Magnesian Limestone of England. They therefore represent the extreme top of the Permian. (4) The discovery is recorded of one of the typical footprints in close proximity with the Permian reptile quarry. (5) The Permian rocks occupy the west of the 'Triassic' area, the true Trias the east. (6) It is suggested that the area was a land-surface during Permian and Triassic times.

References.

1. Hardaker, W. H. "The 'Permian' Rocks of Hampstead": Q.J.G.S., vol. lxviii, p. 639, 1912.
2. Hickling, G. "Footprints from the Permian of Mansfield": Q.J.G.S., vol. lxii, p. 125, 1906.
3. —— "British Permian Footprints": Proc. Manch. Lit. and Phil. Soc., vol. liii, No. 22, 1909.
4. Huene, F. von. "Ein primitiver Dinosaur aus der mittleren Trias von Elgin": Geol. u. Paläont. Abh., n.f., viii, Heft vi, p. 23, 1910.
5. —— "Über einen echten Rhynchocephalen aus der Trias von Elgin": Neues Jahrb. f. Mineralogie, vol. ii, p. 29, 1910.
6. —— "On the Age of the Reptile Faunas contained in the Magnesian Conglomerate at Bristol and in the Elgin Sandstones": Geol. Mag., 1908, p. 99.
7. Pabst, W. "Die Tierfährten in dem Rothliegenden Deutschlands": Nov. Act. Acad. Cæs. Leop.-Carol., vol. lxxxix, p. 338, 1908.
8. Shrubsole, R. L. "The Relationship of the Permian to the Trias in Nottinghamshire": Q.J.G.S., vol. lxvii, p. 75, 1911.
9. Watson, D. M. S. "The 'Trias' of Moray": Geol. Mag., Dec. V, Vol. VI, p. 103, 1909.

V.—Note on the Highland Border Series, near Aberfoyle.

By T. J. Jehu, M.A., M.D., F.R.S.E., F.G.S., Lecturer in Geology at the University of St. Andrews.

The rocks of this series form an interrupted belt along the southern border of the Highlands from Stonehaven on the east to the island of Arran on the west, and they appear again on a more extensive scale in Ireland. In Scotland the series consists of cherts or jaspers and shales, sometimes associated with limestones and with some peculiar igneous rocks. The age of the series has been for years a matter of controversy. Many geologists have held that these rocks are of pre-Cambrian age, but Messrs. Peach & Horne in their volume on *The Silurian Rocks of Britain* (Mem. Geol. Surv., 1899) remarked on the close resemblance of the rocks of this belt to some of the Arenig rocks in the Southern Uplands of Scotland, and the belt has been marked on the Geological Survey maps as doubtfully Lower Silurian.

Many years ago the remains of Radiolaria were detected by Dr. Peach in the cherts near Gualaan, east of Loch Lomond. Later Dr. R. Campbell recorded the discovery of fossils in the black shales, jaspers and cherts intercalated in a series of crushed green igneous rocks north of Stonehaven (GEOL. MAG., N.S., Dec. V, Vol. VIII, 1911).

The discovery of fossils in the Chert and Black Shale Series at Aberfoyle was announced in *Nature*, June 6, 1912, and a further communication was made at the meeting of the British Association, Dundee. The fossils were found in pale-grey chert bands, 1 to 3 inches thick, in an exposure on the south-east side of the Bofrishlie Burn, about 400 yards north-west of Arndrum. The remains occur in muddy films in the chert. The great majority of the fossils are hingeless Brachiopods. The collection was submitted for examination to Dr. Peach, who determined the following forms:—

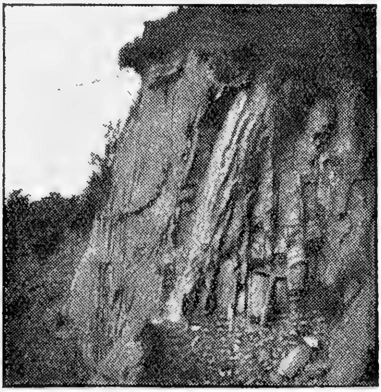


FIG. 1.—The fossiliferous Chert beds, Aberfoyle.

BRACHIOPODS.

1. *Acrotreta.* Specimens of this genus are by far the most common. There appear to be many examples of the species *A. Nicholsoni*, Dav. This is a form common in the Glenkiln (Upper Llandeilo) Black Shales. It occurs in Arenig, Llandeilo, and Bala rocks in the Southern Uplands.
2. *Obolella.* Species indeterminate; several specimens found. In one, the first fossil discovered in the region, both the external and internal casts are shown.
3. *Obolus.* Species indeterminate; a few specimens found.
4. *Lingulella.* Species indeterminate; several specimens found. One specimen shows the internal septum.

PHYLLOCARID CRUSTACEANS.

Two specimens were obtained which appear to be allied to *Lingulocaris.*

ANNELIDS.

The flattened chetæ of Polychæte worms, longitudinally striated, like some which have been described by Walcott. Annelid jaws.

OTHER OBSCURE FORMS.

Among these are what may possibly be pieces of skin of an Arthropod allied to *Eurypterus*. An obscure Graptolite referred to later.

The following remains were found in cherts on the hill-top just above the road where the old aqueduct crosses the valley, opposite the Drum of Clashmore :—

1. Flattened chetæ of annelids preserved in iron pyrites.
2. Casts from which iron pyrites nodules have sprung out and which look very like the casts of Radiolaria.

The fossils obtained from this district were on exhibition at Dundee, at the British Association meetings, 1912, and they were examined by Dr. Ami, F.R.S. Can., of Ottawa. In a letter sent subsequently to Dr. Horne, he stated that the fossils closely resemble those obtained from Upper Cambrian beds belonging to the Quebec Group. His opinion was based partly on the Brachiopods and partly on the presence of an obscurely preserved Graptolite resembling *Retiolites ensiformis*, Hall, a type characteristic of the Sillery Sandstones of the Quebec Group (Upper Cambrian). The great interest attaching to the identification of a Graptolite from the Highland Border rocks was at once recognized, and the specimen was sent to Miss G. L. Elles, Cambridge, for examination. She has kindly supplied the following description:—

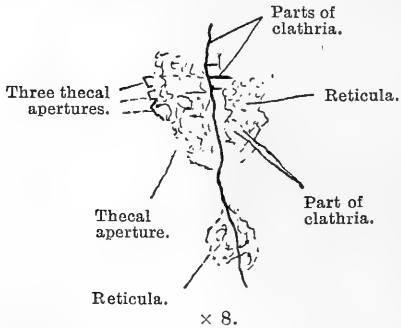


FIG. 2.—SKETCH OF AN OBSCURE GRAPTOLITE FROM ABERFOYLE.

"The specimen appears to me to show traces of thecæ, with a fairly well-developed reticula and clathria. It would appear to belong to Retiolitidæ. The strands belonging to the clathria are the median longitudinal strand and several lateral fragments seen on its left side; those on the right are more obscure. The reticula is of much the same nature as that of *Plegmatograptus selula*, but this Graptolite has no well-developed clathria. Four thecal apertures are discernible, three close together on the extreme left and one some little distance below them. The fact that none are seen on the right is probably due to the fact that the left side of the polypary is turned towards the observer, the right being turned away."—*G. L. Elles.*

The evidence afforded by the fossils shows that the Highland Border Series is of Lower Palæozoic age—probably Upper Cambrian or Lower Ordovician. The field relations of the rocks of this series to the rocks which succeed them on the north are by no means clear. The working out of this problem will throw further light on the true stratigraphical position of the metamorphic rocks in the Southern and Central Highlands.

VI.—The Zone of *Offaster pilula* in the South English Chalk.

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

II. Isle of Wight.

THE zone of *Offaster pilula* is probably exposed on the coast in West Sussex on the foreshore near Bognor, but the nearest cliff exposures to those of East Sussex are those of the Isle of Wight, at Culver Cliff and Scratchells Bay. In both of these the Chalk is so highly inclined that only a very small area of each bed can be reached; and the condition of the accessible surface is such as to make it most improbable that anything beyond the broad outlines of the subzone of abundant *O. pilula*, which is the key and pith of the zone of *O. pilula*, will be detected.

The first of these exposures in the natural order going westwards from Sussex is Culver Cliff, but that is notoriously abnormal, and it is better to take first Scratchells Bay.

A. *Scratchells Bay.*

One of the peculiarities of Scratchells Bay is that it offers only one secure landing-place, in the extreme east corner, under the Grand Arch, so that the middle of the bay, where the zone of *O. pilula* was to be expected, can only be reached by plodding past exposures of the zone of *M. cor-anguinum*, the *Uintacrinus* band, and the zone of *Marsupites*. It was necessary to identify the latter, or at any rate its highest beds, in order to get a starting-point for the zone of *O. pilula*, and I took the opportunity of attempting to identify the other boundaries which must be passed. The westward face of the Grand Arch I knew from Dr. Rowe's work[1] to be occupied by *cor-anguinum* chalk; this was abundantly flinty and seemed to be quite devoid of marl seams. For some way westwards along the bay the chalk continued to be flinty and marlless; then came a short outburst, some 10 feet across, of marly veins, at which I made close but fruitless search for *Uintacrinus*; then for some distance the chalk was again marlless, until there appeared a solitary definite seam of marl, in the neighbourhood of which I again made fruitless search for *Uintacrinus*. It was succeeded by more marlless flinty chalk, and then there appeared a strong tabular seam of flint, which was single in the upper part of the cliff, but forked at its base. Two and a half feet above this there was a strong marl seam, the first of many. Search in the neighbourhood of this marl seam yielded nothing significant below it, but one or two Crinoid brachials in the 2½ feet of chalk immediately above it and a definite plate of *Uintacrinus* in the next 2 feet. It seems, therefore, that the base of the *Uintacrinus* band may be identifiable with this easily recognizable marl seam, which also marks a substantial lithological change, marl seams continuing to be more or less prevalent well up into the *quadratus* zone. (In this respect the section is markedly parallel with that of Seaford Head.

[1] *Coast Sections*, V, p. 228.

There also the *cor-anguinum* chalk is practically free from seams of marl, which set in 4 feet below the flint line taken by Dr. Rowe as the base of the *Uintacrinus* band,[1] and then continue to occur frequently right up to the *quadratus* zone.)

I was able to trace *Uintacrinus* upwards definitely for 40 feet, and 13 feet higher I found what appeared to be a plate of it. Eight feet higher I found my first plate (a very smooth one) of *Marsupites*, and was able to trace plates of *Marsupites* up to a strong marl seam 52 feet higher. For a further 16 feet I found small and dwarf brachials, with one or two dwarf Crinoid plates, and *Terebratulina Rowei* in abundance. These beds by analogy with the Sussex sections I include in the zone of *Marsupites*. This would give a thickness of 129 feet between the base of the *Uintacrinus* band and the top of the zone of *Marsupites*, of which apparently 53 feet should be definitely assigned to the *Uintacrinus* band, and 68 feet to the zone of *Marsupites*, leaving 8 feet between them of a relationship at present uncertain. These 8 feet I assign for the present to the *Uintacrinus* band in conformity with my treatment of a similar blank area in Hants, thus making a total of 61 feet for the band.

Having fixed my upper limit of the zone of *Marsupites*, the next feature likely to be identified is the incoming of *O. pilula* at the base of the subzone of abundant *O. pilula*. I sought *O. pilula* in vain for 53 feet of chalk, which carried me on to the concrete platform mentioned by Dr. Rowe. There I found *O. pilula* for 10 feet. Then I failed to find it again for 22 feet, which carried me to the edge of the central fall, which entirely obscures, at the foot of the cliff, a thickness of chalk which I made out to be 27 feet, and in which, where accessible in irregular patches higher up, no *O. pilula* was found. The first bed to emerge from the fall on its west side is a foot of chalk between two strong marl seams, and in this bed and for a further 13½ feet *O. pilula* occurred in abundance. The highest beds of this chalk were visible in reefs standing out of the shingle, and it was easy to see that in the highest 2½ feet the Offasters were of the exceptional size characteristic of the top of the zone of *O. pilula* in Hants and Sussex. It therefore seems certain that the zone of *O. pilula* of Hants and Sussex is recognizable in Scratchells Bay with an approximate thickness of 53 feet for the lower subzone and 74 feet for the upper subzone.

Above the zone of *O. pilula* the zone of *Actinocamax quadratus* extended some 200 feet, according to my measurements, to the approximate position of the boundary determined by Dr. Rowe. My measurements are therefore, when summarized—

	feet.
Uintacrinus band	61
Zone of *Marsupites*	68
Zones of *O. pilula* and *A. quadratus*	327
	456

[1] I have found brachials, and perhaps a plate of *Uintacrinus*, between this flint line and the marl seam below it, so making the correspondence perfect.

These measurements compare very curiously with Dr. Rowe's, which were—

	ft.	in.
Uintacrinus band	34	6
Marsupites band (= my zone of *Marsupites*)	47	0
Zone of *A. quadratus* (= my zones of *O. pilula* and *A. quadratus* combined)	343	0
	423	6

It will be seen that our grand totals differ by less than 7 per cent, yet our totals for the *Uintacrinus* band and for the *Marsupites* zone or band differ much more largely, so that it is probable that our lower and upper boundaries of these items are placed in very different positions. Unfortunately Dr. Rowe does not give any indications by which the points at which he fixed these boundaries can be identified in the field, and no close comparison can be made. The same difficulty has repeatedly confronted me in trying to compare my results in Dorset with those obtained by Dr. Rowe, and I have therefore thought it desirable to give in each case summarized sections with sufficient details concerning all indications of boundaries on which I have relied to enable subsequent workers to identify them in the field and use any records of mine which may fill lacunæ in their own. In these sections I have aimed at mentioning every definite marl seam and flint tabular met with, and I believe that with their aid any desired point can be readily picked out. Flint seams are to be assumed to occur at frequent intervals unless otherwise stated.

The following section is intended to serve the above purpose for Scratchells Bay.

East End of *Mucronata* Fall at Beach Level.

		ft.	in.	ft.	in.
Zone of *B. mucronata.*	Chalk with two marl seams			16	0
	Marl seam marking probably the boundary of the *mucronata* zone fixed by Dr. Rowe.				
Zone of *A. quadratus.*	Chalk	57	0		
	Marl seam.				
	Chalk with a flint tabular	4	0		
	Marl seam.				
	Chalk with a flint tabular	30	0		
	Marl seam.				
	Chalk	36	6		
	Chalk with three marl seams	6	0		
	Chalk	10	6		
	Marl seam.				
	Chalk with a red sponge bed	27	0		
	Marl seam.				
	Chalk with six marl seams	27	0		
	Marl seam.				
	Chalk	1	6		
	Flint seam.				
	Chalk	1	0		
				200	6
	Carried forward . .			216	6

Zone	Subzone	Belt	Beds	ft.	in.	ft.	in.
			Brought forward . . .			216	6
			Marl seam.				
Zone of *O. pilula.*	Subzone of abundant *O. pilula.*	Upper belt of *O. pilula.*	Chalk with *O. pilula* of maximum size .	1	6		
			Flint seam.				
			Chalk with *O. pilula* of large size . .	1	0		
			Marl seam.				
			Chalk with *O. pilula* and three marl seams	11	0		
			Marl seam.				
			Chalk with *O. pilula*	1	0	14	6
			Marl seam emerging from fall at base of cliff.				
		Lower *Cinctus* belt.	Chalk hidden by fall at base of cliff (about)	27	0		
			Chalk with six marl seams	22	0	49	0
		Lower belt of *O. pilula.*	Chalk with *O. pilula*, two marl seams, and two flint tabulars, 3 feet apart. . .			11	0
			Strong marl seam.				
	Subzone of *E. scutatus*, var. *depressus.*		Chalk with a marl seam	4	0		
			Strong marl seam.				
			Flintless chalk, apparently the belt mentioned by Dr. Rowe	5	6		
			Marl seam.				
			Chalk with eight marl seams and two flint tabulars	39	0		
			Strong marl seam.				
			Chalk	4	0	52	6
			Strong marl seam.				
Zone of *Marsupites.*			Chalk with *Terebratulina Rowei* and small Crinoid brachials and plates.	7	3		
			Strong flint tabular.				
			. . . . . .	2	6		
			Strong marl seam.				
			. . . . . .	6	6		
			Very strong marl seam with many fragments of *Inoceramus* just below it.				
			Chalk with *Marsupites* at 6 feet down .	12	0		
			Marl seam.				
			Chalk with three marl seams and a thin flint tabular	30	0		
			Very strong marl seam.				
			Chalk	7	0		
			Flint seam.				
			Chalk with marly veins and *Marsupites* .	2	6	67	9
			Flint seam.				
Uintacrinus band.			Chalk with marly veins	5	4		
			Flinty chalk	2	3		
			Flint seam.				
			Chalk with *Uintacrinus*	3	3		
			Line of large flints.				
			Chalk with three marl seams	10	0		
			Strong flint seam with what looks like a silicified marl seam just below it.				
			Chalk	2	6		
			Strong marl seam.				
			Chalk	20	0		
			Marl seam.				
			Chalk	9	0		
			Marl seam.				
			Chalk with three marl seams and *Uintacrinus*	9	6	61	10
			Marl seam with forking flint tabular 2 ft. 6 in. below it.			473	1

The detailed correspondence between the upper belt of *O. pilula* and the chalk immediately above it here and in Hants and Sussex is very striking.

B. *Culver Cliff.*

Not one word too much in dispraise of this exposure of the Chalk between the zones of *Belemnitella mucronata* and *Marsupites* has been said by Dr. Rowe.

The following is a summarized section down from a strong marl seam running along the north side of the ledge which Dr. Rowe took as the lower boundary of the zone of *B. mucronata*:—

Combined zones of *O. pilula* and *A. quadratus*.

	ft.	in.	ft.	in.
Chalk with six marl seams			48	0
Marl seam.				
Chalk			60	0
Marl seam.				
Chalk with one flint tabular and a pair of pseudo-tabulars			107	6
Marl seam.				
Chalk with one marl seam			12	0
Marl seam.				
Chalk with one flint tabular			25	9
Marl seam.				
Chalk			6	9
Marl seam.				
Chalk			48	3
Marl seam.				
Chalk with eight marl seams and three flint tabulars			46	9
Flint seam (lowest in descending series).				
Flintless chalk	2	0		
Marl seam.				
Flintless chalk	5	6		
Nodule bed	1	0		
Marl seam.				
Flintless chalk	2	0		
Marl seam.				
Flintless chalk		6		
Nodule bed	1	0		
Flintless chalk	3	0		
Marl seam.				
Flintless chalk		6		
Nodule bed	2	0		
Flintless chalk	3	0		
Marl seam.				
Flintless chalk	1	6		
Flint tabular.				
Flintless chalk	2	6		
Marl seam.				
Flintless chalk	1	3		
Marl seam.				
Flintless chalk	3	0		
Flint tabular.				
Flintless chalk	2	6		
Marl seam.				
Flintless chalk	2	0		
Marl seam.				
Flintless chalk	1	9		
Marl seam.				
Flintless chalk	1	6		
Nodule bed	1	0		
Flintless chalk	8	3		
			45	9
Carried forward			400	9

	ft.	in.	ft.	in.
Brought forward . .			400	9
Marl seam, approximate upper boundary of the zone of *Marsupites* fixed by Dr. Rowe.				
Flintless chalk	5	0		
Nodule bed	1	0		
Flintless chalk	5	0		
? Nodule bed	1	0		
Flintless chalk	3	0		
			15	0
			415	9

First flint seam of new series.

The figures for the lowest 20 feet are estimates only, the clean surfaces being well out of reach.

It will be observed that my grand total for the combined zones of *O. pilula* and *A. quadratus* is identical with that obtained by Dr. Rowe. So also is it for the flintless chalk, but in this case there is a wide discrepancy between his details and mine, which latter I have therefore given very fully. There appeared to me to be at least five nodule beds, the highest being given by a slip a deceptive appearance of being a continuation of the one just below it, and the bed which I have marked as possibly a nodule bed at the base of the section looked as if it must be either that or a strongly marked sponge bed; it is out of reach, and the point could not be settled.

I have not attempted to apportion this chalk between the zones of *O. pilula* and *A. quadratus*, as I have not yet been able to identify with certainty even the position of the subzone of abundant *O. pilula*, without which the upper boundary of the zone of *O. pilula* can hardly be fixed. As it is undoubtedly present in typical aspect in Sussex to the east, in Hants to the north, and, as we have just seen, in Scratchells Bay to the west, it might be confidently expected to occur here also in typical aspect, if it were not that the chalk succeeding the zone of *Marsupites* here is notoriously abnormal lithologically and that the abnormal lithological conditions may have been accompanied by abnormal palæontological conditions which affected the whole of the zone of *O. pilula*. The most I can say at present is (1) that if the upper boundary of the zone here is of the usual nature it can hardly be reached for 300 feet at any rate from the *mucronata* zone and has to be sought in the remaining 100 feet; and (2) that just by the nodule bed I mark as 2 feet thick I have obtained several Asteroid ossicles, all belonging apparently to a small, gently sloping variety of *Crateraster quinqueloba*, Goldf., which is abundant in the subzone of abundant *O. pilula* in Sussex and is the exact antithesis of the high, large, and steep-sided form which culminates in the subzone of *E. scutatus*, var. *depressus*. There is reason to anticipate that Mr. Spencer will be able to show that such an occurrence has an important bearing on the question which of the subzones is present at this point. As far as I can recollect this is also the point at which in company with Mr. Griffith many years ago I found the *O. pilula* and (much-eroded) Belemnite which are referred to by Mr. Jukes-Browne (*The Cretaceous Rocks of Britain*, vol. iii, p. 93) and Dr. Rowe (*Coast Sections*, V, p. 247).

Dr. Rowe's account hardly does justice to the extraordinary abundance of marl in the flintless chalk. In a thickness of 32 feet there are ten seams, and three of them were noted as being of exceptional thickness.

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

NOTICES OF MEMOIRS.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AUSTRALIA, AUGUST, 1914.

I.—Address to the Geological Section by Professor Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S. (President of Section C).

EXACTLY eighty-three years from the day of our arrival at Sydney, Eduard Suess was born in London.[1] Thus the day, as much as the circumstances of our meeting so far from home, serves to remind us of one who was great enough to recognize the fact that geological evidence from any part of the world has the same value as that obtained in the little continent which has been the most prolific in the products of nomenclature and the most productive in textbooks.

Since the days of Charles Lyell no geologist has been so conspicuously successful in analysing the accumulated mass of evidence, in bringing together the essential facts from all lands, and in compensating for the local excesses of literature. Only those of us who, by long absence from Europe, have felt the full disadvantages of having to express our thoughts in alien terminology can appreciate the real value of Suess's great work. His death since our last meeting makes a conspicuous mark in the history of geological science.

A meeting of the British Association in Australia brings home forcibly to the members of Section C the fact that British Imperial geology is really "the science of the Earth"; partly for this reason one feels inclined to get outside the science and take a survey of some of its suburbs. Not many of them have been left untraversed by my distinguished predecessors in this chair; but there has been of recent years a tendency to avoid the inner Earth, which has rightly been described as "the inalienable playground of the imagination", and consequently, therefore, common land to the geologist as well as the geodesist, physicist, and mathematician.

The geologist who looks below the purely superficial phenomena of the crust is generally regarded as straying beyond his province; but the desire to see the birth-certificate of some of the strange and often unacceptable 'causes' which the mathematical physicist offers us is a pardonable form of curiosity. Our ideas regarding intra-telluric conditions are even proving to be of economic value, one of the most recent and unexpected results of the kind being that just established by Baron von Eötvös in Hungary,[2] whose predictions now bid fair to outstrip those of the 'diviner'! Having noticed the low gravity values over the great cores of rock-salt in the Transylvanian 'Schlier', he finds similar defects of gravity in the same region over certain of the Sarmatian and Pontian domes, which probably owe their shape to subterranean salt-plugs and are now found to be great storehouses of natural gas, which, with or without liquid petroleum, is commonly found with the saline 'Mediterranean' facies of the Upper Tertiary in Eastern Europe. Baron von Eötvös also finds that on the eastern margin of the Great Hungarian Plain, where the younger Tertiary beds are completely concealed by a mantle of alluvium, mud-volcanoes and

[1] See life of Eduard Suess, GEOL. MAG., January, 1913, pp. 1–3, and Portrait, Plate I. His obituary appeared in GEOL. MAG., June, 1914, p. 288.

[2] Comptes Rendus, XVII[e] Conf. de l'Assoc. Géodés. Internat., Hamburg, 1912, pp. 427, 437.

gas-springs are sometimes found in areas of marked gravity defect, and some of these are now also being drilled for natural gas.

When our ideas of the state of affairs below the surface thus begin to yield economic results, there is hope that they are at last steadying down, becoming more settled, and indeed more 'scientific'. It may not be unprofitable, therefore, to review some of the advances recently made in developing theoretical conceptions regarding the interior of the Earth that are of direct importance to geologists. In undertaking this review I am conscious of the fact that I shall be traversing ground that is generally familiar to all, and much of it the special property of specialists whose views I hesitate to summarize and should not dare to criticize. As the author of the *Ingoldsby Legends* said of the only story that Mrs. Peters would allow her husband to finish, "The subject, I fear me, is not over new, but will remind my friends—

'Of something better they have seen before.'"

The intensity and quantity of polemical literature on scientific problems frequently varies inversely as the number of direct observations on which the discussions are based: the number and variety of theories concerning a subject thus often form a coefficient of our ignorance. Beyond the superficial observations, direct and indirect, made by geologists, not extending below about one two-hundredth of the Earth's radius, we have to trust to the deductions of mathematicians for our ideas regarding the interior of the Earth; and they have provided us successively with every permutation and combination possible of the three physical states of matter—solid, liquid, and gaseous.

Starting, say, two centuries back with the astronomer Halley, geologists were presented with a globe whose shell rotated at a rate different from that of its core. In more recent times this idea has been revived by Capt. (Sir) F. J. Evans (1878) to account for the secular variations in the declination of the magnetic needle.

Clairault's celebrated theorem (1743), on which Laplace based the most long-lived among many cosmogonies, gave us a globe of molten matter surrounded by a solid crust. Hopkins demanded a globe solid to the core, and, though his arguments were considered to be unsound, his conclusions have been revived on other grounds; while the high rigidity of the Earth as a body has been maintained by Lord Kelvin, Sir George Darwin, Professor Newcombe, Dr. Rudski, and especially by the recent observations of Dr. O. Hecker, supplemented by the mathematical reasoning of Professor A. E. H. Love. Hennessy (1886), however, concluded that the astronomical demands could be satisfied by the old-fashioned molten Earth in which the heavier substances conformed to the equatorial belt.

As long ago as 1858 Herbert Spencer suggested that, on account of its temperature being probably above the critical temperature of known elements, the centre of the Earth is possibly gaseous. Late in the seventies Dr. Ritter revived the idea of a gaseous core surrounded by a solid crust, and this was modified in 1900 by the Swedish philosopher, Svante Arrhenius, whose globe with a solid crust, liquid substratum, and gaseous core is now a favourite among some geologists.

Wiechert (1897) supposed that the core of the Earth, some 5,000 kilometres in radius, is composed mostly of iron with a density of 7·8, while this is surrounded by a shell of lithoidal material having a density of about 3·0 to 3·4; and this great contrast in density is about that which distinguishes the iron meteorites generally from those of the stony class. Arrhenius also assumes that iron forms the main part of the central three-quarters, and he shows that this distribution of substance may still be consistent with his theory of a gaseous core: indeed, he not only imagines that the whole of the iron nucleus is gaseous, but also most of the siliceous shell, for he leaves only 5 per cent of the radius as the depth of the solid and liquid shells combined.

But the variety of ideas does not end with theories on the present constitution of the globe. Poisson required the process of solidification to begin from the centre and to progress outwards, while other mathematicians had been happy with the Leibnitzian *consistentior status* as the first external slaggy crust.

Since the days of Laplace all naturalists have been forced to accept the idea of a solar system formed by the cooling and condensation of a spheroidal gaseous nebula; and all except those geologists who have vainly searched for traces of the primeval crust have been happy in this belief.

Recently, however, Dr. F. R. Moulton and Professor T. C. Chamberlin in America have brought together arguments from different points of view to construct the solar system by the aggregation of innumerable small bodies, 'planetesimals,' which have gathered into knots to form the planets. Thus the Earth is supposed to have grown gradually by the accretion of meteoritic matter, and even now, although the process has nearly ceased, it receives much meteoritic material from outside.

With the Chamberlin–Moulton theory there must have been a time when the gravity of the Earth was insufficient to hold an atmosphere of any but the heavier gases, such as carbon dioxide; later, the Earth became heavy enough to retain oxygen, then nitrogen, water-vapour, and helium; while even now it may not be sufficiently attractive to prevent the light and agile molecule of hydrogen from flying off into space. With the growth of the young globe, the compression towards the centre produced heat enough to melt the accumulated fragments of meteoritic matter, and the molten material thus formed welled out at the surface. Such volcanic action is supposed to have predominated at the surface until an appreciable atmosphere was formed, and became charged with water, when the now familiar processes of weathering, erosion, and deposition produced the film of 'rust' which geologists know as sedimentary rocks.

With this last addition to the variegated array of theories about the physical condition of the Earth and about its genealogy, the scientific world began again to settle down into serenity, comforted by the happy feeling that all, at any rate, agree in regarding the Earth as a gradually cooling body, with many millions of years still before it. Then came the discovery of radium, and with it at first an assurance that geologists were justified in claiming a long past, to be followed by a longer future than the most optimistic philosopher had dared before to assume with our apparently limited store of Earth-heat. Now, however, Professor Joly warns us that if the deeper parts of the globe contain anything near the proportion of radio-active bodies found by him in the superficial rocks, we may even be tending in the other direction; that, instead of a peaceful cooling, our descendants may have to face a catastrophic heating; the now inconspicuous little body known as the Earth may indeed yet become famous through the Universe as a new star.[1]

To add to the variety of ideas regarding the present state of the Earth's interior, Professor Schwarz, of Grahamstown,[2] concludes that our volcanic phenomena can be accounted for on the assumption that the main mass of the Earth below a superficial layer is cold and solid throughout, being composed, like the meteorites, largely of unaltered ferromagnesian silicates and iron.

Thus, we see, whole fleets of hypotheses have been launched on this sea of controversy: some of the craft have been decoyed by the cipher-signals of the mathematician; some have foundered after bombardment by the heavy missiles classically reserved for use by militant geologists; others, though built in the dockyard of physicists, have suffered from the spontaneous combustion set up by an inadvertent shipment of radium. Still, some of these hypotheses are yet apparently seaworthy, and it may not be unprofitable to compare them with recently acquired data.

The nearest approach to actual observation with regard to the state of the Earth's interior has been obtained by the seismograph, designed to record the movements of seismic waves at great distances from the disturbing earthquake. Some of the waves sent forth from an earthquake centre travel through the Earth, and some travel around by the superficial crust, the former reaching the distant seismograph before the latter. The seismograph, by its record of

[1] J. Joly, *Radioactivity and Geology*, 1909, pp. 168–72.

[2] E. H. L. Schwarz, *Causal Geology*, 1910.

the waves that travel *through* the Earth, has thus given a certain amount of information regarding the state of the Earth's interior which R. D. Oldham aptly regards as analogous to that given by the spectroscope[1] with regard to the inaccessible atmosphere of the Sun.

The existence of two groups of earthquake waves—those passing through, and those passing near the surface around the Earth—has long been recognized; but R. D. Oldham[2] has shown that the waves passing through the Earth are of two kinds, travelling at two different speeds.

The record on the distant seismograph thus shows three well-marked phases: the first phase, due to waves of compression passing through the Earth's interior; the second phase, due to waves of distortion,[3] also passing through the Earth's interior; and the third phase, recorded by the waves which pass around the arc along the superficial crust.

The third phase is always recorded at a time after the occurrence of the shock proportional to the arcual distance of the recording seismograph from the earthquake centre, the records of several large earthquakes showing an average speed for the waves of about 3 kilometres per second. The rates of propagation of the waves giving the first and second phases are both much greater than of those forming the third phase; and up to an arcual distance of about 120° from the earthquake's centre the rate of their propagation increases with the distance. It is thus assumed that the waves giving rise to the first and second phases in each distant seismographic record, by following approximately along the chord of the arc between the place of origin and the instrument, pass through deeper layers of the Earth when the seismograph is farther away, the material at greater depths being presumably more elastic as well as denser.

But Oldham[4] has shown that when the seismograph is as much as 150° from the earthquake centre there is a remarkable decrease in the mean apparent rate of propagation of the waves giving the second phase in the record, from over 6 to about 4½ kilometres per second. There is also a drop, although not nearly so marked, in the apparent speed of the waves of the first phase when transmitted to a seismograph 150° or more distant from the earthquake origin. Oldham concludes that this decrease of apparent rate for waves travelling through the Earth to places much more than 120° distant is due to their passing into a central core, four-tenths of the radius in thickness, composed of matter which transmits the waves at a markedly slow speed. Thus the earthquake waves which emerge at a distance not greater than 120° from their origin do not enter this central core, while those which pass into the Earth to a greater depth than six-tenths of the radius are supposed to be refracted on entering, and again on leaving the postulated core, in which the rate of transmission of an elastic wave of distortion is very much slower than in the main mass of the Earth around. In consequence of the refraction of these waves on passing through the central core, places situated at about 140° from an earthquake origin should be in partial shadow, due to the great dispersion of the distortional waves, and the few records made so far by seismographs thus situated with regard to great earthquakes show that there is either no, or at most a doubtful, record for the second phase, which is known to be due to the so-called distortional waves.

[1] In his Presidential Address to the Geological Society of London in 1909, Professor W. J. Sollas (Proc. Geol. Soc., 1909, p. lxxxvii) credits H. Benndorf (Mitth. Geol. Ges. Wien, i, p. 336, 1908) with this pretty analogy, but Oldham has the precedence by just two years (cf. Quart. Journ. Geol. Soc., vol. lxii, p. 456, 1906).

[2] Phil. Trans., ser. A, vol. cxciv, pp. 135–74, 1900.

[3] There is more complete agreement regarding the fact that two distinct sets of waves give rise to the so-called preliminary tremors indicated by a seismographic record than about the nature of the waves. Cf. R. D. Oldham, Phil. Trans., loc. cit., and O. Fisher, Proc. Camb. Phil. Soc., vol. xii, pp. 354–61.

[4] Quart. Journ. Geol. Soc., vol. lxii, pp. 456–75, 1906.

Oldham's deductions are based confessedly on a small number of earthquake records—he considered fourteen examples only—but the conclusions based on a small number of trustworthy records, from which variations due to the different methods of marking the phases are eliminated, are more reliable than those for which there are imperfect distant records as well as doubts regarding the exact times of the disturbances. If these observations, however, be confirmed by further records, we are justified in assuming that below the heterogeneous crust there is a thick shell of elastic material, fairly homogeneous to about six-tenths of the radius, surrounding a central core, four-tenths in thickness, which possesses physical properties utterly unlike those of the outer layers; for in this core the 'distortional' waves are either damped completely or are transmitted at very much lower speeds than in the shell.

One cannot consider this interesting inference from the seismographic data without being reminded of the contention of Ritter, Arrhenius, and Wilde regarding the possibility of a persistent gaseous core still above the critical temperature of the substances of which it is composed. According to Ritter,[1] the gaseous core is surrounded by a solid shell. Dr. Wilde[2] postulates the existence of a liquid substratum and a gaseous core within a solid crust, the two outer shells having a thickness that is 'not very considerable'. Arrhenius assumes from purely physical considerations that the solid crust is only about 25 miles thick, that below this it is possibly in a molten condition for about 150 miles, and that the rest is a gas largely composed of iron under a pressure so great that its compressibility is not much less than that of steel.

The whole of these conclusions, being based on assumptions regarding the physical properties of matter under conditions of temperature and pressure that are well beyond those of actual experience, must be put on a plane of science well below that occupied by the investigations initiated by Oldham, who opens up a line of research in which, as said before, the seismograph may justifiably be compared with the spectroscope as an instrument for observing some inaccessible regions of Nature.

The mathematician apparently finds it just as easy to prove that the Earth is solid throughout as to show by extrapolation from known physical values that it must be largely gaseous. As Huxley said in his Presidential Address to the Geological Society in 1869, the mathematical mill is a mill which grinds you stuff of any degree of fineness, but, nevertheless, it can grind only what is put into it; and the seismograph thus offers a new source of substantial grist. Now that it is fairly certain that some of the earthquake waves pass through the deeper parts of the Earth, it is obvious that a fruitful development of science will follow successful efforts to introduce precision in recording, and uniformity of expression in reading, seismographic records.

Oldham[3] has pointed out another way in which analysis of seismographic records may lead to information regarding intra-telluric conditions by comparing the records of waves that pass under the oceanic depressions with those that are sub-continental for the whole or most of their paths. By comparing the records in Europe of the Columbian earthquake of January 31, 1906, with those of the San Francisco quake in the following April, there was a greater interval

[1] A. Ritter, "Untersuchungen über die Höhe der Atmosphäre und die Constitution gasformiger Weltkörper": Wiedemann's *Ann. d. Phys. und Chem.*, vol. v, pp. 405, 543, 1878; vol. vi, p. 135, 1879; vol. vii, p. 304, 1879; vol. viii, p. 157, 1879.

[2] *On the Causes of the Phenomena of Terrestrial Magnetism*, pamphlet, 1890, p. 2. The idea that the Earth's magnetism is due to the electricity generated by the friction between the shell and the core, rotating with a different motion, was suggested by Dr. Wilde in 1902 (Mem. Manch. Lit. Phil. Soc., vol. xlvi, pt. iv, p. 8, 1902). A similar suggestion based also on Halley's conception of a separately rotating inner core was made previously by Capt. (Sir) F. J. Evans in 1878 ("Remarkable Changes in the Earth's Magnetism": *Nature*, vol. xviii, p. 80).

[3] Quart. Journn. Geol. Soc., vol. lxiii, pp. 344–50, 1907.

noticed between the first and second phases of the Californian earthquake—an interval greater than can be accounted for by mere difference of distance between the origin of the shock and the recording instruments. The seismic waves which passed from Columbia to Europe must have travelled under the broadest and deepest part of the North Atlantic basin, while those from California ran under the continent of North America, crossed the North Atlantic not far south of Iceland, and approached Europe from the north-west, the wave paths throughout being under continents or the continental shelf of the North Atlantic. There is thus suggested some difference between the elastic conditions of the sub-oceanic and the sub-continental parts of the crust—a difference which, judging by the particular instances discussed, may extend to a depth of one-quarter of the radius, but is not noticeable in the waves which penetrate to one-third of the radius below the surface.

Obviously these data must be multiplied many times before they can be regarded as a reliable index to a natural law; but it is significant that this indication of a difference between the physical nature of the sub-oceanic and sub-continental parts of the crust is in rough correspondence with the conclusions previously suggested on quite other grounds.

In his Presidential Address to the Geological Section of the British Association at Dover in 1899, the late Sir John Murray drew attention to the chemical differentiation which has been going on between the continents and the oceans since the processes of weathering and denudation commenced. By these processes the more siliceous and specifically lighter constituents are left behind on the continents, while the heavier bases are carried out to the ocean. It is to this process that Professor T. C. Chamberlin[1] also ascribes the origin of the depressions in which the oceanic waters have accumulated. As a corollary of the planetesimal theory, Chamberlin assumes that water began to be forced out of the porous surface blocks of the accumulated meteoritic material when the Earth's radius was between 1,500 and 1,800 miles shorter than it is now; at that time pools of water began to be formed on the surface, and the atmosphere, just commencing its work, began the operation of leaching the heavier bases out of the highlands. Growth of the world proceeded by the infall of planetesimals, and while those meteorites that fell on the highlands became deprived of their soluble bases, those that fell into the young ocean were merely buried unaltered. Thus by the time the Earth reached its present size its crust under the oceanic depressions must have developed a chemical composition differing from that under the continents. According to the deduction suggested by Oldham from the seismographic records, there is a noticeable difference in the sub-oceanic areas to depths of between 1,000 and 1,300 miles—a layer in which the followers of Chamberlin's theory might reasonably expect some physical expression of the partially developed chemical differentiation.

The occurrence of denser material below the ocean has, of course, long been assumed from the deflection of the plumb-line, and was accepted by Pratt for his theory of compensation, as well as by Dutton as a wide expression of the theory of isostasy. Chamberlin[2] thus explains the general prevalence of basic lavas in oceánic volcanoes.

The apparent heterogeneity indicated in the outer shell of the Earth to depths of 1,000 miles is naturally in conflict with the assumption that from 30 miles or so down the materials are in a liquid condition; at any rate, the idea conflicts with Fisher's extreme conception of the liquid substratum, in which the fluidity is supposed to be sufficient for the production of convection currents, upwards beneath the oceanic depressions, spreading horizontally towards the continents, and thence downwards to complete the circuit.

The idea that changes of azimuth and of latitude may be brought about by the sliding of the Earth's crust over its core has been put forward more than

[1] Chamberlin and Salisbury, *Geology*, vol. ii, pp. 106–11, 1906.
[2] *Geology*, vol. ii, p. 120, 1906.

once to account for the climatic changes of past geological ages—the occurrence of temperate or even warm climates on parts of the crust now within the Polar circles, and glacial conditions at the sea-level in countries like India, Australia, Africa, and South America, which are now far from the Polar ice-sheets and in some cases near or within the Tropics. Professor E. Koken, of Tübingen,[1] in an elaborate memoir entitled *Indisches Perm und die Permische Eiszeit*, attributes the idea of a sliding crust to Mr. R. D. Oldham; but a similar suggestion was put forward by the late Sir John Evans twenty years before the publication of Mr. Oldham's paper,[2] and when the theory was restated in more precise form, ten years later,[3] it was subjected to mathematical criticism by J. F. Twisden, E. Hill, and O. Fisher.[4]

Sir John Evans suggested that this movement of the crust was inevitable as a consequence of the moulding of the orographical features and consequent redistribution of weights; but Twisden came to the conclusion that the re-arrangement of the great inequalities on the Earth's surface would be insufficient to produce any appreciable sliding of the order required to make material differences in the climate of any place.

Oldham,[5] who was writing at the time in the field in India and thus away from literature, put forward the idea in 1886 as an independent thought, and made use of Fisher's new theory regarding the existence of a fluid stratum between the solid crust and the supposed solid core to account for the shifting of places relative to the axis of rotation from the equatorial region even to the Polar circles. Oldham drew attention to the recorded small changes of latitude at certain observatories and to the probable changes of azimuth in the Pyramids of Egypt—evidences of a kind which have since been greatly enlarged by the work of Sir Norman Lockyer and others.

The movements assumed to have taken place during the human period are of course small; and to project from them changes as great as the transfer of lands from the Polar circle to the Tropics has the objection that characterizes a surveyor's use of 'unfavourable' triangles in a trigonometrical survey. Before admitting, therefore, that these small changes of latitude and of azimuth may be classed with the palæo-glacialists' evidence as data of the same kind, though so utterly different in magnitude, it is desirable briefly to examine the geological evidence regarding past ice ages in extra-polar areas.

From the records of ancient glaciations we might omit those of the pre-Cambrian rocks of North Ontario and the pre-Upper Cambrian of Norway, as these areas are nearer the Poles than many places which were certainly covered with ice-sheets during the youngest, or often so-called Great, Ice Age. But besides these we have evidence of glaciation in the Cambrian or possibly pre-Cambrian rocks of South Australia at a latitude of 35° or less; in South Africa there were two or more distinct glacial periods before Lower Devonian times in slightly lower latitudes; while in China similar records are found among rocks of the Lower Cambrian, or possibly of older age, at a latitude of 31° N.

The glacial boulder-beds found at the base of our great coal-bearing system in India belong to the same stratigraphical horizon as the glacial beds found in South Africa, certain parts of Australia, and in parts of Brazil and São Paulo near or within the Southern Tropic.

[1] *N. Jahrb. für Min. u.s.w.*, p. 537, 1907.

[2] J. Evans, "On a possible Geological Cause of Changes in the Position of the Axis of the Earth's Crust": Proc. Roy. Soc., vol. xv, p. 46, 1866.

[3] J. Evans, Presidential Address, Proc. Geol. Soc., 1876, p. 105.

[4] J. F. Twisden, "On possible Displacements of the Earth's Axis of figure produced by Elevations and Depressions of her Surface": Quart. Journ. Geol. Soc., vol. xxxiv, p. 35, 1877. E. Hill, "On the possibility of Changes in the Earth's Axis": Geol. Mag., 1878, pp. 262, 479. O. Fisher, "On the possibility of Changes in the Latitude of Places on the Earth's Surface": Geol. Mag., 1878, pp. 291, 551.

[5] Geol. Mag., 1886, p. 304.

These glacial beds are often referred to in the geological literature as Permo-Carboniferous in age; but Professor Koken regarded the formation in India as Permian. Other valuations of palæontological evidence, similar to that relied on by Professor Koken, place these beds at a distinctly lower horizon in the European stratigraphical scale, and recent work by officers of the Geological Survey of India in Kashmir tends to confirm this latter view; we now regard the base of our great coal-bearing system in India—the horizon of the glacial boulder-beds—as not much, if at all, younger than the Upper Coal-measures of Britain.[1] The precise age of the horizon is not very important for our present consideration: the important point is that in or near Upper Carboniferous times a widespread glaciation occurred throughout the area now occupied by India, Australia, and South Africa. The records of this great glaciation are thus found stretching northwards beyond the northern as well as southwards beyond the Southern Tropic.

Now, on the assumption that the cold climate in this region was due to a movement of the crust over the nucleus, Professor Koken has produced an elaborate map of the world, showing the distribution of land and sea during the period, with the directions of ocean currents and of ice-sheets. The Permian South Pole he places at the point of intersection of the present 20th parallel S. and 80th meridian E.—that is, at a point in the Indian Ocean about equidistant from the glaciated regions of India, Australia, and South Africa. The Permian North Pole is thus forced to take up its position in the centre of Mexico, while the Equator strikes through Russia, Italy, West Africa, down through the South Atlantic and round by Fiji to Vladivostock.

The very precision of this map reduces the theory on which it is based to a condition of unstable equilibrium. If glacial conditions were developed in India, Australia, and South Africa by a 70° movement of the crust, were the movements to and from its assumed position in Permian times so rapid that the glaciation of these widely separated areas appear to be geologically contemporaneous? If such movements had occurred, instead of evidences of glaciation over a wide area at the *same* period, we ought rather to find that the glaciation in each of the widely separated points occurred during distinctly *different* geological periods.

But that is not the only weak spot in the evidence. The Permian (or Permo-Carboniferous) glaciation of Australia took place on the east and south-east of the continent as well as in Western Australia, and the eastern ice-sheets would thus have been active within 30° of Professor Koken's Permian equator. There are still three other serious pieces of colour-discord in this picture. In the State of São Paulo—that is, within Koken's 'Permian' tropics—Dr. Orville Derby has described beds which strikingly recall the features of the Upper Palæozoic glacial beds of India and South Africa. It is possible that these are due to the work of glaciers at a high level; but, since the publication of Professor Koken's memoir, other occurrences of the kind have been described by Dr. I. C. White in different parts of Brazil, and there is a general correspondence between the phenomena in South America and those in the formations of the same age in the Indian, Australian, and African regions.

Then, too, if we accept this expression of the physical geography during Upper Palæozoic times, we must carefully explain away the suspicious breccias and brockrams which have been regarded by many geologists as evidences of a cold climate during Permian times in the Urals, the Thüringerwald, the English Midland and Northern counties, Devonshire and Armagh—places that would lie on or near Koken's 'Permian' equator. Finally, we find the hypothetical Permian North Pole in a locality which has failed to produce any signs of glaciation.

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

[1] H. H. Hayden, Rec. Geol. Surv. Ind., vol. xxxvi, p. 23, 1907.

II.—*Papers read in Section C (Geology), Meeting of British Association, Australia, August, 1914.*

(1) Deserts (Definition, Causes, and Soils). By Professor J. W. Gregory, F.R.S.

THE term 'desert', according to modern usage, means a country which is unoccupied in consequence of having an arid climate. Various exact limits of the conditions that established deserts have been proposed. Thus Sir John Murray adopted the desert limit as a 10 in. rainfall, and William Macdonald (*Dry Farming*, p. 91, 1911) that of 20 inches as the limit of the arid region. Goodchild, on the other hand, rejected numerical limits as arbitrary and impracticable, and proposed a more elastic definition based upon a general deficiency of moisture. Walther has pointed out that deserts cannot be precisely defined on biological, morphological, or climatic grounds.

The factors that control the development of desert are not only climatic. The geological structure of the district has an important influence. The presence of rocks which are very permeable owing to porosity of jointing, and which crumble into coarse grains, contributes to desert conditions. Geographical situation is also important, for a plateau which has a free drainage to adjacent lowlands is more easily converted into desert than an area with no easy escape for its subterranean water.

The climatic influence depends not only upon the total amount of rainfall but upon its distribution through the year. Thus a country where the rainfall is in the late summer and autumn may be economically desert, whereas the same rainfall at a more suitable season would render the country fertile. The Transvaal, for example, is hampered by its only certain rains falling between November and March. Temperature and the complex group of factors which determine the rate of evaporation also have an important influence.

Hence the development of desert is not determined by any rigid minimum of rainfall, but by the balance between the many conditions which govern the utilization of the rain.

Deserts are most easily produced and least curable where the rainfall is low, the temperature is high, the wind is strong, and the country consists of a plateau where there is an easy drainage to the adjacent lowlands. On a high plateau the elevation, by lowering the temperature and cooling the air uplifted on to it, tends to secure rain, though if it easily drains to the lowlands the main value of the rain may be on them.

Proximity to the sea is quite consistent with a desert development, for if the sea-water be colder than the land, the capacity of the air for moisture is increased as it blows ashore and a sea-wind may therefore act as a drying and not as a moisture-carrying agent.

Desert and non-desert conditions have frequently alternated in the same district. Thus in the British area there is evidence that desert conditions prevailed during the times of the Torridon Sandstone, the Old Red Sandstone, the Permian, the Trias, and there is evidence of an arid climate in Ireland during part of the Lower Kainozoic. It has been suggested that the existing deserts are now increasing, but the evidence (recently summarized in the *Geographical Journal*, vol. xliii, pp. 148–72, 293–318, 1914) indicates that there has been no general expansion of the desert areas, which are, however, in some places shifting their positions in consequence of local climatic changes.

Deserts are not absolutely incurable, and, owing to a better knowledge of how to use their slight and irregular rainfall, many once-desert areas are now in profitable occupation. When suitably watered, deserts may be extremely prolific; for their soils are often rich in immediately available plant-foods which have accumulated during the long period of rest. The desert soils are often very deep and their crops are nourished from an unusually thick layer. The desert soils especially accumulate salts of potash and lime, which would be leached out of them with a heavier rainfall.

Australian soils have as a rule less than the usually accepted minimum of phosphoric acid required for cultivability. Thus, according to the analyses collected by Professor Cherry, English soils have ·098 per cent of phosphoric acid, American ordinary soils ·116, and American clay soils ·207 ; yet the heavier soils of Victoria have only ·06 and the light soils of the mallee only ·047.

Professor Cherry's results are confirmed by a varied series of 267 soil analyses from Germany, Holland, Spain, Hungary, Jersey, Sweden, Russia, Java, Sumatra, India, Sandwich Isles, the Congo, the Cameroons, Senegambia, German East Africa, South Africa, and Madagascar. The number includes 22 British and 57 from various outlying parts of the United States of America. In these 267 analyses the average of phosphoric acid is ·157 per cent.

Most soils contain more phosphoric acid in the soil than in the subsoil—an advantage which Australian soils do not share. A series of 220 analyses, collected for me by my assistant, Mr. P. Brough, which show the composition of various soils and their subsoils, give an average of ·158 of phosphoric acid in the soil and ·135 in the subsoil; and, excluding a couple of subsoils in which the result is so high that there must be an inclusion of some phosphatic fragment, the ratio of phosphoric acid in soil to subsoil is 16 to 13. In some cases the soil may owe its excess of phosphoric acid to manure; but the excess is often shown in cases in which the land has not been manured.

This series of analyses confirms the generally accepted fact that Australian soils are exceptionally low in phosphate and that outside Australia the soil is usually more phosphatic than the subsoil.

The only explanation of these two abnormal features of Australian soils that appears at all satisfactory is that proposed by Professor Cherry; according to his interpretation the phosphatic accumulation in the soil is due to the action of mammals, and owing to the poverty of Australia in mammalian life no such phosphatic enrichment of the soil has taken place. Soils, therefore, in Australia, which appear to be incurably barren, may, owing to their other excellent qualities, prove of high value if their poverty in phosphoric acid be remedied by manure.

(2) Note on the Occurrence of Loess Deposits in Egypt and its Bearing on Change of Climate in Recent Geological Times.[1] By H. T. Ferrar, M.A., F.G.S.

At a recent meeting of the Association Dr. Hume and Mr. Craig submitted the view that there had been no change, except that of gradual desiccation, in recent geological times in Egypt. Since their paper was published, evidence that the change of climate has not been uniform has been recorded from neighbouring countries. The following short paper is intended to show how Æolian desertic deposits may be interstratified between freshwater beds without any change of climate.

In the northern delta of Egypt are great stretches of flat land a few feet above sea-level. These areas are covered by ordinary Nile alluvium and remain damp during the winter months but dry in summer. Owing to the evaporation which takes place during the spring and early summer, soluble salts accumulate at or near the surface of the soil, rendering it incoherent and powdery. Winds are now able to lift and transport this material until it is arrested by the roots of halophyte plants or other obstacles. Here also are deposited the dead shells of helices, and occasionally also the remains of land animals, such as the jackal, rat, bird, lizard, or snake, which have been seen frequenting dust-dune areas. In fact, the dust dunes of Northern Egypt, known as Kardud to the inhabitants, are local deposits of Loess.

A depression of the land of only a few feet, and such as that which has taken place since Roman times in Egypt, would cause another fluviatile layer containing the common shell *Cyrena fluminalis* or a lacustrine bed to be superimposed upon them. It is thus manifest that a desertic deposit interstratified between two freshwater beds is not necessarily a proof of change of climate.

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(3) The Physiography of Arid Lands (as illustrated by Desert Egypt). By W. F. Hume, D.Sc., F.R.S.E., A.R.S.M., Director Geological Survey of Egypt.

The characters of an arid land cannot be separated from its past history, and in Egypt five physiographic features of first importance have to be considered. These are—

1. A belt of deep impressions in the extreme west, the famous Oases.

2. The broad waterless expanse of the Western or Libyan Desert, to the west of the Nile, and the corresponding limestone plateau region (the Maaza Limestone Plateau) to the east of the river.

3. The Nile Valley with its Delta.

4. The Wilderness of the Red Sea Hills and Sinai with its rugged mountains and tortuous valleys.

5. The Red Sea and its narrow prolongations, the Gulfs of Suez and Aquaba, together with the coastal plains.

Each of these divisions requires separate treatment. The paper

[1] By permission of the Director-General of the Egyptian Survey Department.

gives a rapid sketch of the geological history of Egypt as known to us at present, the formation of the ancient core of pre-Cambrian or Palæozoic sediments, volcanic rocks with invasion by granitic magmas, the brief Carboniferous marine advance, and later the much more important Jurassic-Cretaceous transgression, which practically affected almost the whole of Egypt, giving rise to the Nubian Sandstone and the important phosphate-bearing Cretaceous Series. The Eocene strata which form the major portion of Central Egypt are probably formed, at the base, of remade Cretaceous material, and only in their upper portions show marked evidence that the underlying sandstones and igneous rocks are undergoing erosion.

The re-arranging of Cretaceous strata eroded during Eocene times is regarded by the writer as explaining the great difficulty experienced in drawing a lithological line of unconformity between the beds of these respective periods, though the faunal differences indicate the great break between them.

Fringing the pre-Eocene and Eocene areas of Egypt are a series of Miocene and more recent formations which are of great interest both from tectonic and economic points of view.

In considering the separate physiographic features it is pointed out:

1. In the formation of the Oases it is necessary to consider the denudation of the area by marine erosion while rising from the sea and the effects of former more humid climatic conditions. Where the Nubian Sandstone or other soft beds have been exposed, as Beadnell has pointed out, the Oases depression without outlet is produced by wearing through wind-blown sand.

2. The Great Plains of the Libyan Desert are regions of low dip, of meagre rainfall, and thus wind is the dominant factor. A sandy region to the north supplies the sand necessary for erosion. The character of the desert surface depends on the nature of the geological strata present. The undulating gravel plateaux, or *serir*, the limestone expanse, the 'melon' country, and the fossil floors are various forms in which the desert presents itself, the main feature being the removal of all particles capable of being transported by wind. These are deposited as sand-falls in the wind-shadows of the Nile Valley scarp or other depressions. The sand dunes which are locally developed are in sharp contrast to the main desert, these probably depending on three main factors—the existence of sandy deposits determining their source of origin, the usual direction of the wind their trend, and the relief of the ground their position.

The Maaza Limestone Region is similar to the Libyan Desert, but has a greater rainfall. It thus presents a fine example of the effects when rain acts during short periods on rock-surfaces affected by temperature variations. Deep ravines, remarkable water-holes, caverns, natural bridges, and surface coloration films due to the trickling down of ferruginous solutions over cliff-walls are among the prevailing features in the southern part of this area.

3. The present course of the Nile Valley appears to depend on three factors: (1) the formation of the syncline, the axis of which it partly follows; (2) the erosion of the softer strata along their outcrops determining the present north–south trend of the major courses

of the river; and (3) the possible effect of the rotation of the earth (Van Baer's law), the stream tending to hug its eastern bank. Attention is called to the region of exceptional erosion where heavy masses of Eocene limestone rest on and have slipped over the subjacent soft Cretaceous marls and slates. These slips must have been connected with greater rainfall and earth-movement as widespread terraces extend in front of the main cliff and rise to some 110 metres above the present river-level. The triple terracing of the Nile is briefly considered.

4. The Mountain Region of the Eastern Desert is essentially an Anticlinal Area, where tension is in excess of compression. The differential movements are considerable, minor folds play a conspicuous part, and great fractures determine earth-features of considerable magnitude. The result is that the masses of granite and metamorphic rocks hidden beneath the surface in Central Egypt are here exposed by denudation, forming the Red Sea Hills and Sinai Mountains.

The different geological formations give rise to very varied surface features. Attention is called to the importance of rain as a sculpturing agent. The soft Nubian Sandstone is easily eroded both by windborne sand and water, giving rise to conspicuous depressions. In the Granitic areas temperature variation breaks up the solid rock, huge domes are produced by flaking off of concentric shells. Dykes give rise to marked differences in surface outline, the harder quartz-porphyries determining the form and general trend of many of the mountain summits, while the softer diabases, being easily eroded, give rise to gullies seaming the precipitous sides of the granitic hills. The general character of the country where schists and volcanic rocks are present is also described.

5. In the Gulf of Suez area another factor has come into play. Here sea-arms project far inland between land-surfaces subject to desert conditions, and their waters become centres of far-reaching chemical activity. Thus coral-reefs are changed to dolomites, sea-shells of carbonate of lime to gypsum, hydro-carbons are in quantities of economic importance, and mineralized areas of lead and zinc ores, of manganese oxide, of iron pyrites, and of sulphur are present in the young Tertiary beds which fill these Red Sea depressions. From Suez to beyond Halaib, that is, throughout the length of Egypt, gypsum forms a conspicuous fringe between the ancient hills and the sea, generally dipping gently seaward on the borders of the Red Sea itself. Further north, in the Gulf of Suez area, the conditions are more complicated. Dyapir, or piercing folds such as have been described by Professor Mrazec in Roumania, are of common occurrence, and there is remarkable interplay between the hard and soft members of the folded series.

The surface structure of an arid land is not only the direct reflex of its geological structure, but also of former climatic change. Many factors in Egypt point to great rainfall in the past, such as gravels of igneous material in the Nile Valley far from their source of origin, masses of travertine in the Oases, the varying terraces of the Nile Valley itself, the evidence of expansive lakes at Kom Ombo, etc.

Though the main features of a desert land depend on the geological structure and in part on past climatic conditions, there are characteristics which are typical of all arid regions. These are far removed from the great marine areas and from the zone of rainfall dependent upon solar activity in lands beneath the Tropics.

These typical desert features have already been referred to, and include—

1. The sweeping of all fine material from the surfaces of the plains by the action of the wind, and formation of plateau summits.
2. Intense scouring of these surfaces by wind-driven sand.
3. The breaking up of the most solid rocks by temperature variation.
4. The formation of sand dunes behind obstructions or where the relief of the ground favours their development.
5. The formation of mushroom-shaped pillars, or standing-out of harder materials on bases undercut by the sand.
6. The formation of sand-worn pebbles of typical angular outlines, the well-known Dreikante.
7. Vermicular markings on limestones, due it may be to etching during the movement of evaporating saline solutions.
8. Formation of desert-crusts by leaching out of the soluble materials contained in the rocks, with evaporation at the surface, resulting in deposition of the oxides of iron and manganese. Mr. Lucas, Director of the Survey Department Laboratory, has made a special study of these desert and river films, the latter probably only differing from desert ones in degree.
9. Flaking off of surfaces in the surface zone affected by temperature variation. Also fracture due to the same cause. Fragments of porphyry, limestone, etc., are often split into a series of parallel flakes standing vertically, their original connexion to one another being clearly indicated by their close juxtaposition.

In the half-desert where rain, though brief, is intensely active while it lasts, a series of interesting phenomena are presented: deep cañon-like valleys, boulder-strewn gullies, saw-back ridges, parallel-dyke country, saline marshes, dry waterfalls or steep precipices in the valley-floors, great talus-slopes.

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(4) The Denudation of Arid Regions by Wind and Water. By Johannes Walther, Professor of Geology and Palæontology in the University of Halle, Germany.

EVERY climatic region is characterized by a different type of disintegration and denudation of soft or softened rock by the agents of erosion. In the nival region a cover of snow protects the surface of the earth during a long period of the year.

In the humid zone and also in the equatorial pluvial region the soil is overgrown by a network of roots and rootlets of millions of plants, which bind together the small particles and protect them against wind and running water.

In arid regions, where the rain is not sufficient to form perennial rivers, and where the vegetation forms isolated patches in the barren country, every particle of soft or disintegrated rock is quickly taken away by the wind or the occasional rainfall. Therefore the general denudation of the land is very powerful. The Egyptian monuments, exposed during 4,000 years to the disintegrating and denuding powers of the desert, offer beautiful examples of the different kinds of dry disintegration, and many of them show very clearly also the transporting effect of the wind.

REVIEWS.

I.—W. W. Nikitin. La Méthode Universelle de Fedoroff. Traduction française par L. Duparc and Mlle V. de Dervies. Two volumes in one; pp. 516 and atlas. Genève, Edition Atar; Paris, Béranger. 30 francs.

THE universal or theodolite methods of investigating the geometrical and optical properties of crystals were first fully described by Professor Fedoroff in the year 1893. The problems connected with the geometrical study are relatively simple, and the original theodolite or two-circle goniometer scarcely admitted of any essential improvement. On the other hand, the full determination of the more important optical constants of a crystal fragment or of a mineral in thin section obviously presents difficulties of a far higher order, which have only been successfully surmounted after the expenditure of much time and ingenuity on the part of the creator of the method and of his pupils, amongst whom the author of the present work must always take the highest place. The employment of the Fedoroff universal stage in its present perfected form cannot fail to revolutionize the optical study of crystals, not merely by reason of the fact that a mineral can be identified with great rapidity, but because it is now possible to determine optical constants with such a high degree of exactitude as to settle within narrow limits the position of the mineral in its isomorphous group. This is especially true of the felspars, the optical data of which have been so extensively and carefully studied.

The work is a translation with many important additions of a comprehensive guide to the use of the universal stage, which was especially written by Professor Nikitin for the use of the students in the St. Petersburg School of Mines. Its scope may be best indicated by the following table of contents:—

Tome i: Introductory chapter on the optical properties of crystals, pp. 1–59. Graphical methods, especially those relating to the use of the Fedoroff stereographic net, pp. 60–91. Description of the universal stage and its adjustment on the polarizing microscope, pp. 92–120. Discrimination of optically isotropic, uniaxial, and biaxial crystals, pp. 121–39. Determinations of the orientation and optic axial angle of a biaxial crystal, pp. 140–89. Approximate determination of the refractive index, 190–237. Recapitulation of methods for a biaxial crystal, pp. 238–49. Uniaxial crystals, pp. 250–69.

Tome ii: Determination of the thickness of the section and of the birefringence, pp. 275–443. Determination by extinction methods of the value of the optic axial angle in cases where the optic axes are inaccessible, pp. 444–86. Birefringence of uniaxial minerals, pp. 487–514.

The atlas contains eight plates, and includes a copy of the well-known stereographic net, as well as several ingenious graphical methods of reducing the observations.

The book contains much original matter which has never hitherto been published in a West European language, and attention may be especially called to the new Nikitin method of determining refractive indices by means of total reflection (pp. 214–37).

With regard to the exposition of the subject-matter, it may be stated that the book shows unmistakable evidence that the author has had great teaching experience and fully realizes which portions are likely to require more detailed treatment. The result is a work which can be confidently recommended to all who desire to avail themselves of the most modern methods of optical study, whether they be petrologists, mineralogists, or chemical crystallographers. Concerning the translation and editing, it need only be said that the high standard for which French writers are justly celebrated is fully maintained.

II.—Catalogue of Scientific Papers, Fourth Series (1884–1900). Compiled by the Royal Society of London. Vol. XIII, A–B. pp. xcviii, 951. Cambridge: University Press, 1914 (July). Price £2 10*s*.

We lose no time in announcing the publication of this volume, which concludes for A and B the one hundred years Catalogue of Scientific Papers undertaken by the Royal Society, the first volume of which appeared in 1867. As a great part of the literature included in this series has never before been accessible in any catalogue, we have waited somewhat impatiently for its appearance. So far as one can judge by a hasty glance through the volume, and an intimate knowledge of the method of compilation, this series shows a marked improvement on those preceding, especially in the attempt to secure a more complete inclusion of serials and their contents, and intelligent specification of authors' names. Of the multitude of papers written it is enough to say that 63,271 titles are included, and the preface admits that "brief notes . . . have not been catalogued owing to inevitable limitations of space". The value of such can only be determined by the worker, to whom in many cases a few lines may be more important than a monograph. We much regret that the University Press have felt obliged to print in so small a type and in so close a form, and think that the insertion of a rule between each entry would have been a great advantage to the reader and to those institutions which have cut up and carded the previous volumes. The spacing suggested would, it is true, have extended to perhaps 150 extra pages, but the advantages would have outweighed the disadvantages considerably; and one would quite as soon pay £3 as £2 10*s*. for the volume, so the matter of price cannot have been the reason, any more than considerations of space, which would not have been more than 6 inches of shelving extra for the series. We are glad to be rid of the numbering of the entries, a troublesome and annoying business to compilers, and a useless thing to readers in such a work. We thank the Cambridge Press for coming to the rescue of the Royal Society and giving us this volume, and we congratulate the Royal Society on the assurance that its great undertaking is now secure to a conclusion.

III.—Economic Geology. By Charles H. Richardson. 8vo; pp. 320, ix, with 133 figures in the text. New York and London: McGraw-Hill Book Company, 1913.

LIKE many textbooks, Professor Richardson's *Economic Geology* has emanated from a series of lectures given to students from year to year. The lectures on which this book is based were commenced some twenty years ago, so that the author is fully justified in now giving them to a wider circle of students. The book deals only with metals and their ores, but the author promises a companion volume on non-metallic minerals, a textbook for which there must be considerable demand.

The treatment of the subject is methodical and simple. Metals are classified as precious, useful, and rare; the 'useful metals' are taken in the order of their chemical separation. Under each metal are considered its properties, ores, origin and distribution of ores, method of extraction and uses. Special chapters deal with the classification and origin of ore deposits, and there is a final chapter giving statistical information.

The work is furnished with an excellent index and is illustrated by 133 photographs and diagrams, carefully chosen from the best books on ore deposits.

W. C. S.

IV.—Canada: Department of Mines. Geological Survey Guide-books. Ottawa: Government Printing Bureau, 1913.

THESE Guide-books were prepared for the use of members of the Twelfth International Geological Congress. They contain a large amount of information relating to the geology and physiography of the various areas visited by members of the Congress.

There is a general introduction to each excursion, followed by a fuller treatment of the country surrounding the special centres of observation, which is copiously illustrated with maps, sections, and photographs. Notes are also given in explanation of the features of the country seen *en route*.

Space does not permit of even a cursory survey of the valuable matter in these little books; it must suffice to give a bare list of contents.

No. 1 (2 parts). Excursion in Eastern Quebec and the Maritime Provinces. (A useful general geological map of Canada, on the scale of 100 miles to an inch, is included.)

No. 2. Excursions in the Eastern Townships of Quebec and the Eastern part of Ontario:—

The Haliburton–Bancroft area of Central Ontario.
Asbestos Deposits of the Province of Quebec.
Mineral Deposits near Kingston, Ontario.

No. 3. Excursions in the neighbourhood of Montreal and Ottawa:—
The Morin Anorthosite Area.
The Monteregian Hills.
Mineral Deposits of the Ottawa District.
Pleistocene—Montreal, Covey Hill, and Ottawa.
Ordovician—Montreal and Ottawa.

No. 4. Excursions in South-Western Ontario:—
Niagara—Iroquois Beach.
The Palæontology of the Guelph, Onondaga, and Hamilton Formations of Western Ontario.
The Palæozoic Section at Hamilton, Ontario.

No. 5. Excursions in the Western Peninsula of Ontario and Manitoulin Island:—
Silurian Section at the Forks of the Credit River.
Ordovician Section on Credit River, near Streetsville.
Algonquin Beach, Glacial Phenomena and Lowville Limestone in Lake Simcoe District, Ontario.
Geology of selected areas on Lakes Huron and Erie in the Province of Ontario.

No. 8 (3 parts). Transcontinental Excursion (Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways).

No. 9. Transcontinental Excursion (Toronto to Victoria and return via Canadian Pacific, Grand Trunk Pacific, and National Transcontinental Railways).

No. 10. Excursions in Northern British Columbia and Yukon Territory and along the North Pacific Coast:—
Prince Rupert and Skeena River.
Yukon and Malaspina.

It will be seen that the territory covered is very extensive, and in fact there are very few areas of geological interest in the Dominion to which one cannot find some reference in these books.

These guide-books will prove invaluable to tourists and also to prospectors and emigrants having some acquaintance with geology and seeking fuller information of the Dominion.

V.—Hudson Bay Exploring Expedition, 1912. By J. B. Tyrrell. Twenty-second Report of the Ontario Bureau of Mines, 1913.

The author describes his journey down the Nelson River from Lake Winnipeg to its junction with the Echimamish, up this river to its head, across the narrow rocky divide which bounds the waters of the Nelson River on the east and then down the Hayes River to York Factory on Hudson Bay.

The Hayes River was surveyed by Professor Stewart, of Toronto, from its junction with the Shamattawa River to its mouth, a distance of 60 miles, while the author made a short expedition up the Shamattawa and also explored the country in the neighbourhood of York Factory.

On the return journey passage was taken to Fort Severn at the mouth of the Severn River, which was ascended in canoes for a distance of 56 miles to the mouth of Fawn River. This river was then ascended for 180 miles to Trout Lake, from which point the route lay southward to Cat Lake, on the waters of the Albany River, passing a number of important lakes on the way.

The general description of the district thus traversed is of much interest. The highest ground consists of a rocky granitic plateau with an elevation of 1,500 feet above the sea in North latitude 52°, West longitude 92°, and from here northwards the ground slopes gradually to Trout Lake, which lies near the northern boundary of the broken country. From Trout Lake northward to Hudson Bay the slope continues at about the same rate, but the rock soon disappears under glacial and post-glacial deposits, and the country is then covered with an even mantle of glacial clay or till, upon which marine sands and clays are often found to rest ; much of the country is flat and occupied by extensive peat bogs.

The geology is discussed under the heads of the different formations: Archæan, composed of granites, gneisses, and other igneous or highly altered sedimentary rocks; Palæozoic, including Ordovician and Silurian limestones and dolomites extending for 60 miles southwards from Hudson Bay; and Pleistocene.

Notes are given on the various exposures and descriptive lists of the Ordovician and Silurian fossils collected. The glaciation is dealt with in some detail, and the different directions of movement of the ice are discussed.

VI.—Geological Surveys.

(1) Portugal. Comunicacões da Comissão do Serviço Geológico de Portugal. Tom. ix, pp. 288, xxiv. Lisbon, 1912–13.

THIS volume includes three papers on the petrology of Portugal by V. Souza-Brandao; also notes (with a tabular analysis) on the organization of the Geological Surveys of Europe. In addition to the papers in Portuguese there are several interesting communications which have been written in French in order to give them the wider circulation which they deserve.

A paper by P. Pruvost records the discovery of fossils in the *schistes à Nereites* of San-Domingos. These beds were described by Delgado and were correlated with the *Nereitenschichten* of Thuringia, which are of Middle Devonian age. The fossils now discovered comprise Brachiopods and Trilobites and include *Clymenia lævigata*, a fauna which places the beds in the Famennian stage of the Upper Devonian.

J. Lambert contributes a description of ten species of echinoids from the Callovian of Cesaréda. Both this and the paper mentioned above are illustrated by excellent plates.

In addition to reports on economic geology, Paul Choffat has published the ninth of a series of biographies of Portuguese geologists—Baron Wilhelm Ludwig von Eschwege (1777–1855). The paper gives a complete résumé of Eschwege's writings and a most interesting account of his efforts to promote the mining industry in Portugal during a most disturbed period of its history.

The tenth series of the "Geological Bibliography of Portugal and its Colonies (1910–12)" contains notices of 154 publications and gives brief analyses of the more important papers.

W. C. S.

(2) UNITED STATES OF AMERICA.—The geology of Alaska is the subject of a brief review in a previous number of this journal (GEOL. MAG., 1914, p. 31), in which six bulletins relating to this territory were noticed. Since then we have received three additional bulletins, Nos. 536, 538, and 542, dealing with the geology of parts of Alaska.

No. 536. The Noatak-Kobuk Region, Alaska. By Philip S. Smith, 1913.—This deals with the geology of the basins of the Kobuk and Noatak Rivers, which drain into Kotzebue Sound. The shores of this part of Alaska were visited by Sir John Franklin in 1826 and by many other Arctic explorers. Having regard to the great difficulty of exploration in this country, the maps produced are extraordinarily complete. Large areas still remain unexplored, but food and fuel are scarce and there seems small prospect of developing any mineral occurrences. A large area is occupied by metamorphosed sediments, possibly Palæozoic, and by Palæozoic limestones, including some beds of Silurian and Devonian age. Carboniferous sandstones and limestones have yielded fossils of Mississippian age. The igneous rocks include altered basalts, in part contemporaneous with Palæozoic limestones; rocks of andesitic and dioritic composition are associated with Lower Cretaceous or Jurassic rocks, and are cut by granitic intrusions and basaltic rocks of late Tertiary age.

No. 538. A Geological Reconnaissance of the Circle Quadrangle, Alaska. By L. M. Prindle, 1913.—The area mapped is situated in the Yukon-Tanana region. Here again there are large areas of Palæozoic sediments, those of pre-Ordovician age being highly metamorphosed. Jurassic and Triassic rocks appear to be absent. Diabase and basalt are associated with the Palæozoic rock, and there are large intrusions of biotite-granite of Mesozoic age. The youngest igneous rocks are late Cretaceous or early Tertiary, and consist of rhyolites, dacites, and basalts.

No. 542. Mineral Resources of Alaska: Report of Progress of Investigations in 1912. By A. H. Brooks and others, 1913.—This is the ninth of a series of bulletins giving preliminary reports on deposits of economic interest and a summary of the mining industry in 1912.

The "Bibliography of North American Geology of 1912, with subject index", by John M. Nickles, 1913 (Bulletin 545), includes all publications bearing on the geology of North America and the adjoining islands, also of Panama and the Hawaiian Islands. It follows the plan of similar bibliographies published annually since 1906.

Other bulletins received are Nos. 531 and 539, both of which are restricted to information having a purely economic bearing.

(3) ALABAMA GEOLOGICAL SURVEY.—We have received Bulletins 13 and 14, being the statistics of the mineral production of Alabama for 1911 and 1912, compiled from the *Mineral Resources of the United States*, by C. A. Abele. The Geological Survey has also issued a third edition of *Iron Making in Alabama*, by Dr. W. B. Phillips, the earlier editions of which were published in 1896 and 1898.

CORRESPONDENCE.

THE GEOLOGICAL SOCIETY'S ABSTRACTS.

SIR,—I have received a letter from the Society stating that it is unusual for Fellows resident abroad to receive the "Abstracts of Proceedings". These publications, with notices of the papers and reports of the discussions, are probably taken as a matter of course by most Fellows in the British Isles, while they may be scarcely known to those elected while in residence abroad. They provide information months earlier, and often contain matter that is not given at all in the "Quarterly Journal". It is easy to give a number of instances where papers have been read and discussed, and the larger publication, when it at last arrives, has only a bare statement of the title. Apart from the value of the account of what the author said, the reports of the discussions are often of the greatest interest to those unable to be present at the meetings. The abstracts promote the objects of the Society by stimulating interest in its larger publications, the contents of which are already familiar in outline on arrival. They are not then put aside to await a more favourable opportunity of cutting the pages, for the recipient knows more or less what is likely to interest him.

If any members are to have the "Abstracts", those resident abroad have the strongest claim. They are unable to attend the meetings and the library is out of reach. The cost of postage on the small publication is the same to most parts of the world and cannot be urged as a reason against general distribution. Instead of these things being recognized, and the Society doing its utmost to give its exiles a more living interest in its work, it slights them by not sending full measure of its publications.

G. W. GRABHAM.

KHARTOUM, ANGLO-EGYPTIAN SUDAN.
July 29, 1914.

OBITUARY.

ALFRED JOHN JUKES-BROWNE, B.A., F.R.S., F.G.S.

BORN APRIL 16, 1851. DIED AUGUST 14, 1914.

WE regret to record the death of Alfred J. Jukes-Browne, which took place, after a brief illness, on Friday, August 14, 1914, at his residence, "Westleigh," Ash Hill Road, Torquay.

Alfred J. Browne was the son of Mr. A. H. Browne, formerly of St. Paul's Crescent, Camden Town. His mother was a sister of Professor J. Beete Jukes, F.R.S. He took the name of his uncle on attaining his 21st birthday and afterwards was known as Alfred Jukes-Browne.

He was educated at Cholmondeley School, Highgate, and thence entered St. John's College, Cambridge, where he passed the Natural Science Tripos in 1874, and took his B.A. degree. He was an ardent student of Natural History, and the writer recalls the pleasure with which young Browne showed him his collection of recent shells all carefully named and arranged by himself. He was always a rather delicate and ailing lad, and in later life never seemed to overcome this weakness of constitution. But his mental energy was remarkable.

On September 7, 1874, A. J. Jukes-Browne was appointed as a temporary assistant on the Geological Survey of Great Britain under Sir Andrew Ramsay and continued on the Survey for twenty-seven years, but retired on account of ill-health in 1901. In 1874 he was elected a Fellow of the Geological Society, and was a recipient of the Lyell Fund in 1885, when the President, Professor T. G. Bonney, F.R.S., spoke of the excellent work Jukes-Browne had done on the Cretaceous formation and in Glacial Geology, and of his papers on the Cambridge Greensand and his Sedgwick prize-essay on the post-Tertiary deposits of Cambridgeshire. Professor Bonney also referred to Jukes-Browne as one of his geological pupils, of whom, as his old college tutor, he was justly proud.

In 1901 the Council awarded Jukes-Browne the Murchison Medal, when the President, Professor J. J. H. Teall, F.R.S., spoke of his numerous writings on the Upper Cretaceous rocks, associating palæontology with his stratigraphical work, of his handbooks on Physical and Historical Geology for Students and his suggestive work on *The Building of the British Isles*, and other valuable services he had rendered to geological science.

He was elected a Fellow of the Royal Society in 1909.

Mr. William Whitaker, F.R.S., an old colleague on the Geological Survey, writes: "By the death of Jukes-Browne science has lost a gallant worker. The greater part of his life was a ceaseless struggle with ill-health and bodily weakness. But the alert and active mind, the resolute spirit, were victorious, and the enfeebled body was not allowed to stop the work that he loved so well, though often it must have delayed it. To those of us especially who have had the blessing of good health it has been a marvel how Jukes-Browne managed to do so much and so well. Under such adverse circumstances most men would have given way, and would have done little or nothing; but he worked until the last. Both in quality and in quantity, in the field even as well as in the study, his work might put to shame many a strong man. He was a worthy nephew of his uncle, Jukes."

His wife and son died before him, but his daughter survives her father.

Between 1871 and 1914 the Geological Magazine credits A. J. Jukes-Browne with ninety-eight papers of his own, and nine joint papers—with C. V. Bellamy on Cyprus; with Wm. Hill on the Gault and Chalk Marl; with Professor J. B. Harrison (2) on the Geology of Barbados; with C. J. A. Meÿer on the Greensand and Chloritic Marl; with J. Milne on the Cretaceous of Aberdeenshire; with J. Scanes on the Upper Greensand of Mere and Maiden Bradley; with W. Whitaker on the Geology of the Wash; and with R. Bullen Newton, F.G.S., on the Devonian of Torquay.

His separate publications include—

Student's Handbook of Physical Geology. Two editions.

Handbook of Historical Geology. 1886.

Handbook of Stratigraphical Geology. 2nd edition, published in 1912.

Handbook, *The Building of the British Isles.* 3rd edition, 1911.

The Cretaceous Rocks of Britain, in 2 vols. Mem. Geol. Survey.

And many other small memoirs for the Geological Survey, and contributions to the Geological Society, Geologists' Association, and the Malacological Society. There is an unpublished MS. of Jukes-Browne's in the Editor's hands dated July 12, 1914, on a Boring at Marston, near Devizes.

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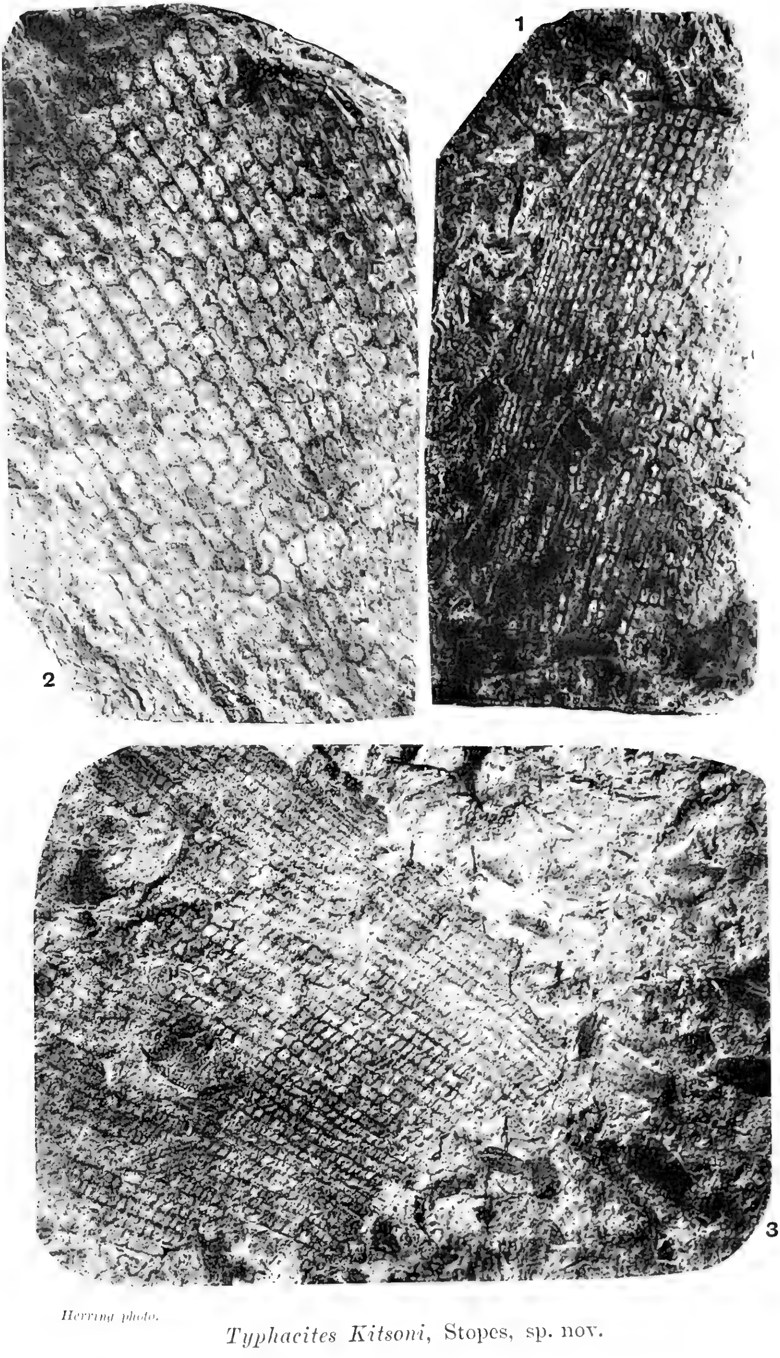


Herring photo.

Typhacites Kitsoni, Stopes, sp. nov.

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

No. X.—OCTOBER, 1914.

ORIGINAL ARTICLES.

I.—A New Cretaceous Plant from Nigeria.

By M. C. Stopes, D.Sc. (Lond.), Ph.D. (Mun.), F.L.S.

(PLATE XXXIII.)

THE available information regarding the fossil plants of Southern Nigeria is of the meagrest description. Consequently great interest lies in the collections of fossil plants brought back from Nigeria last year by Mr. A. E. Kitson, F.G.S., and it seems worth while to publish a brief account of what appears to be a new species of Monocotyledon from among them.

Mr. Kitson's collections of fossil plants, of both Cretaceous and Tertiary age, are extensive, and include specimens which obviously represent a large number of different genera, the majority being species of dicotyledonous leaves. It is greatly to be deplored, however, that the material is so fragmentary; the local accidents of deposition were evidently unfavourable to plant petrifaction.

The one species which forms the subject of the present short note is apparently part of the base of a monocotyledonous leaf. There are a number of specimens of this between the layers of reddish-brown impure shale of Cretaceous age which is literally packed with more or less macerated vegetable fragments (see Fig. 3, Pl. XXXIII). The exact locality of their occurrence is given by Mr. Kitson as in the Azuta River, east of the crossing of the Udi–Okwoga road over it, i.e. roughly 120 miles in a direct line north-west from Calabar on the coast of Southern Nigeria.

Regarding the geology of the region Mr. Kitson[1] writes: "The oldest known sedimentary rocks are Cretaceous marine and estuarine fossiliferous shales, mudstones, limestones, sandstones, and grits. They flank the Oban hills, and extend in a great mass northward into Northern Nigeria; also westward under the Udi highlands, where they grade into freshwater beds of similar character, and contain a valuable black coal-field, discovered by myself and Mr. E. O. Thiele. In the Abakaliki district, in marine Cretaceous strata, there are lodes of silver-lead, zinc, and iron ores, formed along fault-lines. Dolerite, basalt, agglomerate, and tuff occur as dykes, sills, or volcanic necks in the Cretaceous area of the eastern province."

Certain of the shales are rich in vegetable remains, and among the innumerable plant-fragments in them which are macerated out of all recognition are a number of net-like impressions varying in area from 1 × 2 up to 8 or 10 cm. These impressions consist of a blackened,

[1] A. E. Kitson, "Southern Nigeria; some considerations of its Structure, People, and Natural History": Geographical Journal, January, 1913, p. 19.

carbonaceous, and characteristically regular meshwork (see Figs. 1–3, Pl. XXXIII). In the majority of cases the mesh is isodiametric, and about 2 mm. across, but toward the edge or base of the specimens the mesh narrows and becomes reduced in size, as is shown in the Text-figure, p. 435, and Fig. 3, Pl. XXXIII. In a few cases the whole of the mesh is finer.

The first point to determine is whether this open mesh represents a normally perforate leaf or macerated portions which retain only the skeletal framework. The former interpretation would seem reasonable were there not a few cases in which a blackened, coaly film lies over part of the area and suggests that it was the surface tissue of a non-perforate leaf lamina. In living reeds a somewhat similar phenomenon can be observed on a smaller scale; the leaf-base in *Typha* partially decays, displaying a regularly perforated skeleton beneath the smooth lamina, and I feel little doubt that the fossils represent old leaf-bases of somewhat similar plants.

Turning now to described species of fossils with which to compare the new Nigerian plant, one finds a number of records of *Arundo*, *Typha*, *Phragmites*, etc., from the Tertiary of many countries. None of these specimens, however, are identical with our fossil, the forms generally being laminæ which only show fine striations formed by the longitudinally running veins and their regular transverse connexions. The same may be said of the forms described by Heer, Unger, Saporta, and others from the Cretaceous, as will be seen in the various original figures, references to which are given in detail in my Cretaceous Catalogue[1] under the generic names. Among the illustrations of comparable forms which I have been able to discover fig. 2*a*, pl. xviii, of Ludwig's[2] paper on the Tertiary species *Phragmites Oeningensis*, Al. Braun, bears considerable resemblance to a fragment of our fossil; but this figure is an *enlargement* of the detail of the leaf; the normal leaf of *P. Oeningensis* has, like the other described fossils of the kind, veins on a much smaller scale than has our new Nigerian form.

The only described fossil of which I am cognisant which bears a real resemblance to the Nigerian ones is that figured by Saporta in 1890,[3] pl. ii, fig. 4. This, both as regards the size of the mesh and the general appearance, comes very close to our fossil. Saporta's fragment, however, is a small one, only 1 × 2 cm. in area, and gives no indication of the potential size of the leaf. Saporta's plant is described under the name *Typhacites rugosus*, and he speaks of this plant and another which he puts in the same genus as "fragments de feuilles de Monocotylées, sans doute amies des eaux stagnantes, que je figure en les rapportant, non sans quelque doute aux Typhacées". The species were associated with the famous *Nelumbium provinciale*,

[1] Marie C. Stopes, *Catalogue of the Mesozoic Plants in the British Museum: The Cretaceous Flora*, pt. i, 1913, pp. 64, 167, 223, etc.

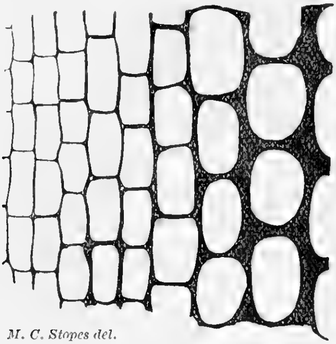
[2] Rudolf Ludwig, "Fossile Pflanzen aus der ältesten Abtheilung der Rheinsch - Wetterauer Tertiär - Formation": Palæontographica, vol. viii, p. 80, 1859–61.

[3] G. de Saporta, *Le Nelumbium provinciale des Lignites crétacés de Fuveau en Provence*, Mém. 5, Soc. Géol. France, 1890, pp. 1–10, pls. i–iii.

Sap. Whatever our Nigerian and Saporta's plants may ultimately prove to be, I think there is little doubt our plant resembles his so closely that, in the present state of our ignorance of the forms, the Nigerian plant should be included in his genus. Therefore I name it in honour of Mr. Kitson, its discoverer.

TYPHACITES KITSONI, n.sp. (Plate XXXIII.)

Diagnosis of such a species is difficult, but may provisionally be as follows: Impressions, presumably of partly macerated or old leaf-bases of considerable size, i.e. exceeding 4 cm. in width and of indefinite length. The regular meshwork of the surface very coarse, each mesh isodiametric, averaging about 2 mm. in diameter, but in parts narrowing down to 1 × 1·5 mm.



M. C. Stopes del.

Drawing of a small portion of the edge of one of the specimens of *Typhacites Kitsoni* (M. C. Stopes). × 3.

Types.—The figured specimens are in the British Museum, Natural History.

Locality.—Azuta River where the Udi Road crosses it, Southern Nigeria.

Discoverer.—A. E. Kitson, Esq., F.G.S.

Horizon.—Cretaceous, Middle (?) or Upper.

Note.—Mr. Kitson authorizes me to state that his large collection of dicotyledons from this and other associated Cretaceous deposits and the Tertiary (?) of other districts in Southern Nigeria is now in the British Museum, and is available for anyone who wishes to describe it.

EXPLANATION OF PLATE XXXIII.

FIG. 1. Specimen of the meshwork of the leaf *Typhacites Kitsoni*, n.sp. Natural size.

,, 2. Portion of a similar specimen enlarged by 2 diameters.

,, 3. Part of the base of another specimen showing the finer mesh, enlarged by 2 diameters. On the right of the figure are seen the numerous macerated fragments of plants which are abundant in these shales.

II.—Some New Genera and Species of Cretaceous Cheilostome Polyzoa.

By W. D. Lang, M.A., F.G.S.

(Published by permission of the Trustees of the British Museum.)

(PLATE XXXIV.)

HERPETOPORA ANGLICA, the genotype of the new genus *Herpetopora*, described in this Magazine,[1] was the name proposed for a new species that hitherto had been wrongly recorded as *Hippothoa dispersa* (Hagenow).[2] It was then remarked that the English form did not belong to the genus *Hippothoa*, of which the genotype is *H. divaricata*[3]; but, while *Herpetopora* was proposed for the English species, no suggestion was made for a genus to include *Hippothoa dispersa* (Hagenow) that certainly could not remain under *Hippothoa*. It is proposed here to describe in detail Hagenow's species, to give it a generic name, and, further, to consider some allied forms.

In 1860 Gabb & Horn published a description of *Hippothoa irregularis* (since redescribed and figured as *Pyripora irregularis*[4]) from the Danian of New Jersey. An examination of a specimen shows that it differs from *Herpetopora* in possessing a boldly beaded termen, and in this it resembles an undescribed form from Faxe and the form hitherto known as *Hippothoa dispersa* (Hagenow). *Pyripora*, however, was founded by d'Orbigny[5] for three genosyntypes, of which one—*Escharina crenulata*, Reuss—was selected as the genotype[6] a year (or two years) after *Pyripora* was introduced. *Escharina crenulata*, Reuss, differs from the three forms under consideration (those from New Jersey, Faxe, and Rügen respectively) in several characters, notably in the form of branching, and neither these nor *Herpetopora*[7] can fall under *Pyripora*. Moreover, of the three, the Rügen form differs from the other two in having dimorphic zoœcia, though neither this feature nor the beaded termen is shown in Marsson's figures. If specimens are suitably painted (with indigo water-colour, for instance) both these characters are plainly seen. The two genera *Allantopora* and *Marssonopora* are proposed, the former to include the Danian species from New Jersey and from Faxe and the latter for the Senonian form from Rügen.

Allantopora, n.g.[8]

Synonymy.[9]

Hippothoa (partim), Gabb: Gabb & Horn, Johnson, Nickles & Bassler.
Pyripora (partim), Conrad in Cook, Gabb & Horn, Meek, Nickles & Bassler, Ulrich & Bassler in Weller, Vine.

[1] Geol. Mag., Dec. VI, Vol. I, pp. 5 and 6, 1914.
[2] For references see p. 438.
[3] Lamouroux, *Exposition Méthodique des genres de l'Ordre des Polypiers*, p. 82, 1821.
[4] For references see p. 439.
[5] D'Orbigny, *Prodrome de Paléontologie Stratigraphique universelle*, vol. ii, p. 263, 1850.
[6] Bronn & Roemer, *Lethæa Geognostica*, vol. ii, pt. v, p. 106, 1851–2.
[7] See a criticism by Canu, *Revue critique de Paléozoologie*, vol. xviii, p. 90, 1914.
[8] ὁ ἀλλᾶς, 'a sausage'; suggested by the strings of zoœcia.
[9] For references see p. 437.

Diagnosis.—Incrusting, uniserial Cheilostome Polyzoa, normally with bilateral branching; zoœcia monomorphic, divided into a proximal caudal and distal capitular portion; termen beaded; extra-terminal front wall well developed proximally, plain with no median ridge or groove; intra-terminal front wall represented by a narrow bevel, tending to become broader proximally.

Genotype.—*Hippothoa irregularis*, Gabb & Horn.

Distribution in time.—Danian.

Remarks.—*Hippothoa* and *Pyripora*, to which genera the species here placed under *Allantopora* have been referred, differ, the former in having a completely calcareous intra-terminal front wall, and the latter in its method of branching and by the presence of avicularia.

Key to the genus Allantopora.

1. Aperture comparatively large; capitular portion of zoœcium pyriform. *A. irregularis* (Gabb & Horn).
2. Aperture comparatively small; capitular portion of zoœcium cylindrical. *A. stomatoporoides*, n.sp.

ALLANTOPORA IRREGULARIS (Gabb & Horn). (Pl. XXXIV, Fig. 1.)

Synonymy.

Hippothoa irregularis, Gabb & Horn, "Description of new Cretaceous Corals from New Jersey": Proc. Acad. Nat. Sci. Philadelphia, vol. for 1860, p. 366.

H. irregularis, G. & H.: Gabb, "Descriptions of New Species of American Tertiary and Cretaceous Fossils": Journ. Acad. Nat. Sci. Philadelphia, ser. II, vol. iv, p. 400, pl. lxix, figs. 18–20, 1860; Timber Creek, New Jersey.

Pyripora irregularis, G. & H.: Gabb & Horn, "Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America": Journ. Acad. Nat. Sci. Philadelphia, ser. II, vol. v, pp. 122, 157, pl. xx, fig. 40, 1862.

P. irregularis, Gabb & Horn: Meek, *Check List of Invertebrate Fossils of North America*, p. 3, 1864; New Jersey.

P. irregularis, Gabb & Horn: Conrad in Cook, *Geology of New Jersey*, p. 723, 1868.

P. irregularis, Gabb & Horn: Vine, "Fifth . . . Report of the Committee . . . on Fossil Polyzoa": Rep. Brit. Assoc. for 1884, p. 169, 1885; Timber Creek.

Hippothoa irregularis, Gabb & Horn: Nickles & Bassler, "A Synopsis of American Fossil Bryozoa": Bull. United States Geol. Surv., No. 173, pp. 153, 154, 1900. Cretaceous: Timber Creek, New Jersey.

Pyripora irregularis (G. & H.): Nickles & Bassler, op. cit., p. 157, 1900. Cretaceous: Timber Creek and Mullica Hill, New Jersey.

P. irregularis, G. & H.: Johnson, "Annotated List of the Types of Invertebrate Cretaceous Fossils in . . . Acad. Nat. Sci. Philadelphia": Proc. Acad. Nat. Sci. Philadelphia, vol. lvii, p. 5, 1905.

P. irregularis, Gabb & Horn: Ulrich & Bassler in Weller, "A Report on the Cretaceous Paleontology of New Jersey": Geol. Surv. New Jersey, Paleontology, vol. iv, Cretaceous Faunas, pp. 167, 337, pl. xxiv, fig. 5, 1907. Vincentown Limesand: North bank of Rancocas Creek north-west of Vincentown, Timber Creek, and near Mullica Hill, New Jersey.

Revised diagnosis.—*Allantopora* in which the capitular portion of the zoœcia is long compared with the caudal portion, pear-shaped, and comparatively large (about ·6 mm. in a proximal-distal direction and ·4 mm. at right angles to this); termen bearing eleven beads, one median and proximal, and five paired decreasing in size distally; proximal part of the extra-terminal front wall short compared with the aperture; intra-terminal front wall a very narrow bevel; aperture large, occupying most of the capitular portion of the zoœcium and nearly a half of its whole length, oval. Sealed zoœcia rare or absent.

Distribution.—Danian, Vincentown Limesand: New Jersey, U.S.A.

Remarks.—The beaded termen, characteristic of the genus *Allantopora*, is not shown in the figures of *A. irregularis* hitherto published; it is very apparent, however, in the British Museum specimen here figured (D. 19186) from the Vincentown Limesand, New Jersey, and undoubtedly belonging to this species.

ALLANTOPORA STOMATOPOROIDES,[1] n.sp. (Pl. XXXIV, Fig. 2.)

Diagnosis.—*Allantopora* with a short caudal portion to the zoœcia and a capitular portion that is cylindrical rather than pear-shaped and tapers very gradually into the caudal portion; the capitular portion is small, about ·5 mm. in a proximal-distal direction, and ·3 mm. at right angles to this; termen with about twelve beads; extra-terminal front wall very large, occupying at least the proximal half of the capitulum as well as lateral areas in the distal portion; aperture oval, small in correlation with the great development of the extra-terminal front wall.

Type-specimen.—British Museum specimen D. 9110; Caroline Birley Collection.

Distribution.—Danian: Faxe, Seeland, Denmark.

MARSSONOPORA,[2] n.g.

Synonymy.[3]

Aulopora (partim), Geinitz, Pictet.
Cellepora (partim), Boll, Hagenow.
Hippothoa (partim), Marsson, d'Orbigny.

Diagnosis.—Incrusting, uniserial Cheilostome Polyzoa, normally with bilateral branching; zoœcia dimorphic; normal zoœcia with capitular and caudal portions, sometimes sealed; termen beaded; extra-terminal front wall well developed proximally, plain, with no median groove or ridge; intra-terminal front wall represented by a narrow bevel, somewhat wider proximally; apertures oval-ovate; avicularia small, situated on the caudal portions of the normal zoœcia.

Genotype.—*Cellepora dispersa*, Hagenow.

Distribution.—Upper Senonian.

Remarks.—Of the different genera in which *Marssonopora dispersa* has been placed, *Aulopora* is a genus of Palæozoic Corals; *Cellepora* was founded by Linnæus[4] for Recent multiserial forms with complete front walls; and *Hippothoa* also has complete front walls.

[1] Invented to mean 'resembling a *Stomatopora*', from the cylindrical shape of the zoœcia.

[2] Named after Theodor Marsson, the monographer of the Chalk Polyzoa of Rügen.

[3] For references see p. 439.

[4] Linnæus, *Systema Naturæ*, 12th ed., vol. i, pt. ii, p. 1285, 1766.

MARSSONOPORA DISPERSA (Hagenow). (Pl. XXXIV, Fig. 3.)

Synonymy.

Cellepora dispersa, nob.: Hagenow, "Monographie der Rügen'schen Kreide-Versteinerungen, Abt. i, Phytolithen und Polyparien": Neues Jahrb. f. Min., etc., Jahrgang, 1839, p. 280; Rügen.

Aulopora dispersa, v. Hag.: Geinitz, *Grundriss der Versteinerungskunde*, p. 629, pl. xxiii*b*, fig. 55, 1846; Obere Kreide: Rügen. [Figure shows the avicularia.]

non *Escharina dispersa* (v. Hagenow): Reuss, *Die Versteinerungen der Böhmischen Kreideformation*, pt. ii, p. 67, pl. xv, fig. 26, 1846. [=*Dacryopora reussi*, see p. 443.]

Cellepora dispersa, v. Hg.: Boll, *Geognosie der deutschen Ostseeländer zwischen Eider und Oder*, Oberer Weisse Kreide, p. 207, 1846.

? *Hippothoa laxata*, d'Orb.: d'Orbigny, *Pal. Franç.*, *Terr. Crét.*, tom. v, 1852, pl. dccxi, figs. 12–15; 1853, p. 386; 1854, p. 1097. Senonian: Meudon, Tours. [Marsson (op. cit. infra, p. 91) gives this species as a synonym of *Cellepora dispersa*, but, judging from the figure, it more resembles a *Herpetopora* with sealed zoœcia.]

H. [*Aulopora*] *dispersa*: d'Orbigny, 1853, op. cit., p. 383; Craie sénonienne de Rügen.

H. [*Aulopora*] *dispersa*, Hagenow: Pictet, *Traité de Paléontologie* . . . vol. iv, 2nd ed., p. 103, 1857. Craie: Rügen.

non *H. labiata*: Novák, "Beitrag zur Kenntniss der Bryozoen der böhmischen Kreideformation": Denk. Akad. Wiss. Wien, vol. xxxvii, pt. ii, p. 86, pl. iii, figs. 1–5, 1877, as stated by Marsson, 1887, op. cit. infra, p. 91. [=*Herpetopora labiata*.]

H. dispersa, v. Hagenow sp.: Marsson, "Die Bryozoen der Weissen Schreibkreide der Insel Rügen": Pal. Abh., vol. iv, pt. i, p. 91, pl. ix, fig. 9, 1887; Rügen.

? non *H. dispersa*, Hagenow: Vine, "Fossil Polyzoa; further additions . . .": Proc. Yorkshire Geol. Soc., N.S., vol. xii, pt. ii, p. 155, 1892; Chatham, Salisbury, and Norfolk. [Probably the Chatham specimens are *Herpetopora anglica* and the others *H. clavigera*.]

? non *Membranipora dispersa*, Hag.: Vine, "Report of the Committee . . . on the Cretaceous Polyzoa": Rep. Brit. Assoc. for 1892, pp. 316, 322, 335, 1893. *Coranguinum* and *quadratus* zones: Chatham and East Harnham. [For probable identities see last entry.]

non = *Crisia Johnstoniana*: Mantell, *The Medals of Creation*, vol. i, p. 285, text-fig. 64 on p. 284, fig. 10, 1844; as stated by Vine, 1893, op. cit., p. 316.

? non *Membranipora dispersa*, Marss.: Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. iii, The Upper Chalk of England (Mem. Geol. Surv. United Kingdom), p. 491, 1904. *Cortestudinarium* zone, Charlton, and *quadratus* zone, Salisbury. [Probably the record from the former horizon is *Herpetopora anglica* and, from the latter, *H. clavigera*.]

? *M. dispersa*, Hag.: Jukes-Browne, op. cit., pp. 268, 491, 1904. *Ostrea lunata* zone: Trimingham, Norfolk.

non *Hippothoa dispersa*, Hagenow: Chatwin & Withers, "The Zones of Chalk . . . between Goring and Shiplake": Proc. Geol. Assoc., vol. xx, pt. v, pp. 394, 416, 1908. *Terebratulina* zone: Gatehampton, Oxon. [The specimen on which this record is founded, British Museum specimen D. 20611, is *Herpetopora anglica*.]

Diagnosis.—*Marssonopora* in which the caudal portions of the zoœcia are very long and the capitular portions are pear-shaped; termen bearing seventeen or eighteen beads decreasing in size distally, in continuous series proximally, but absent from the extreme distal edge; extra-terminal front wall well developed proximally; aperture oval-ovate, occupying about two-thirds of the length of the capitulum; avicularia very small; one (or occasionally two) on many of the caudæ, with oval apertures, constricted rather distally of the middle. Sealed zoœcia rare.

Distribution.—Upper Senonian, zone of *Belemnitella mucronata*: Rügen I., German Baltic.

Remarks.—Marsson (for reference see synonymy) does not mention either the beaded termen or the avicularia, nor do his figures show these characters (though the avicularia appear in Geinitz's figure, see above). They become, however, strikingly clear when the specimen is painted with some dark colour. Doubtless the lack of some such method was the cause of Marsson's overlooking these points; for there can be no doubt of the identity of the Rügen specimens (British Museum specimens D. 11498, D. 15376, and D. 15423) showing these characters with *M. dispersa* as interpreted by Marsson.

It has been shown already that of the three genosyntypes of d'Orbigny's genus *Pyripora*, *Escharina crenulata*, Reuss, must be taken as the genotype. The other two species were *Escharina dispersa*, Reuss (*non* Hagenow), and *Escharina perforata*, Reuss. A glance at Reuss' figure of *Escharina dispersa* will show that it is not *Cellepora dispersa*, Hagenow (just described as *Marssonopora dispersa*), since the front wall is complete. But beyond this, and that it is uniserial, it is difficult to say from the figure what its affinities are. There is, however, an undescribed uniserial Cheilostome occurring rarely in the English Chalk, with a complete front wall, and *Escharina dispersa*, Reuss, may be placed provisionally in the genus now made for its reception.

Dacryopora, n.g.[1]

Synonymy.[2]

Diazeuxia (partim), Canu.
Escharina (partim), Bronn, ? Morris, Reuss, Vine.
Hippothoa (partim), Gabb & Horn, Manzoni, d'Orbigny, Pictet, Vine.
Membranipora (partim), ? Vine.
Microporella (partim), Vine.
Pyripora (partim), d'Orbigny.

Diagnosis.—Incrusting, uniserial Cheilostome Polyzoa, normally with bilateral branching; zoœcia monomorphic, divided into a proximal caudal and a distal capitular portion; termen, except distally, indicated by a contour on the complete front wall at which the slope of the front wall changes; distally it coincides with the lateral and distal edges of the orifice, and bears one or more pairs of spines; extra-terminal front wall comparatively small and slightly arched; intra-terminal front wall entirely calcareous, highly arched, often bearing a median ridge; aperture semicircular or slightly cribrilinid.[3]

Genotype.—*Dacryopora gutta*, new species.

Distribution in time.—? Cenomanian to Senonian.

[1] τό δάκρυ, 'a tear,' 'a drop,' from the shape of the zoœcium.
[2] For references see these authors' names under the several species.
[3] i.e. of the general shape of the orifice in the family Cribrilinidæ.

Remarks.—Without seeing the specimens themselves it is impossible to know the detailed structure of the three species here included with *D. gutta* in *Dacryopora*. As far as can be seen, however, they conform better with *Dacryopora* than with any other genus, and, consequently, are provisionally placed here. Of the various genera under which they have been placed, *Membranipora*[1] and *Pyripora*[2] have incompletely calcareous front walls, *Microporella*[3] and *Escharina*[4] were founded for several Recent multiserial species, and *Hippothoa*[5] and *Diazeuxia*[6] have myriozoid[7] apertures.

Key to the genus Dacryopora.

I. Zoœcia elongate, capitula nearly thrice as long as broad; caudæ very short. *D. simplex* (d'Orbigny).

II. Zoœcia short, capitula one to two and a quarter times as long as broad.

- *a.* Zoœcia with very long caudæ.
  1. Zoœcia more or less parallel-sided . *D. gutta*, n.sp.
  2. Zoœcia fusiform . . . . *D. elegans* (d'Orbigny).
- *b.* Zoœcia with very short caudæ . . *D. reussi*, nom. nov.

Dacryopora simplex (d'Orbigny).

Synonymy.

Hippothoa simplex, d'Orb.: d'Orbigny, *Pal. Franç.*, *Terr. Crét.*, vol. v, pl. dccxi, figs. 5–8, 1852; op. cit., p. 385, 1853; op. cit., p. 1092, 1854. Cenomanian: Sarthe.

H. simplex, d'Orbigny: Pictet, *Traité de Paléontologie* . . . , 2nd ed., vol. iv, p. 103, 1857. Cenomanian.

H. simplex, d'Orb.: Gabb & Horn, Proc. Acad. Nat. Sci. Philadelphia for 1860, p. 366.

H. simplex, d'Orb.: Gabb, Journ. Acad. Nat. Sci. Philadelphia, ser. II, vol. iv, p. 400, 1860.

H. simplex, d'Orb.: Gabb & Horn, Journ. Acad. Nat. Sci. Philadelphia, ser. II, vol. v, p. 157, 1862.

non *H. simplex* (d'Orb.): Vine, Quart. Journ. Geol. Soc., vol. xlvi, pp. 486, 461, 1890. Red Chalk: Hunstanton. (Vine's specimen No. 40, B.M. specimen D. 2052.)

? *H. simplex*, d'Orb.: Vine, Proc. Yorks. Geol. Soc., N.S., vol. xi, pt. iii, pp. 385–6, 396, 1891. Red Chalk: Hunstanton.

? *Membranipora* (?) *simplex*, d'Orb.: Vine, Rep. Brit. Assoc. for 1890, p. 396, 1891. Red Chalk: Hunstanton.

? *Hippothoa simplex*, d'Orb.: Vine, Proc. Yorks. Geol. Soc., N.S., vol. xii, pt. ii, p. 156, 1892. Gault: Barnwell, Cambridge.

[1] De Blainville, *Manuel d'Actinologie*, p. 447, 1834. Includes eleven genosyntypes.

[2] D'Orbigny, loc. cit., see p. 436, 1850.

[3] Hincks, Ann. Mag. Nat. Hist., ser. IV, vol. xx, p. 526, 1877. Genotype, *Eschara ciliata*, Pallas.

[4] Edwards, in Lamarck, *Histoire Naturelle des Animaux sans Vertèbres*, 2nd ed., vol. ii, p. 230, 1836.

[5] Lamouroux, *Exposition Méthodique des genres de l'Ordre des Polypiers*, 1821, p. 82. See p. 436.

[6] Jullien, *Mission Scientifique du Cap Horn*, 1882–3, tom. vi, Zoologie—Bryozoaires, p. 28, 1888. Genotype, *Cellepora hyalina*, Linnæus, *Systema Naturæ*, 12th ed., vol. i, pt. ii, p. 1286, 1767.

[7] i.e. of the general shape of the apertures in the family Myriozoidæ.

Diazeuxia simplex (d'Orb.): Canu, "Revision des Bryozoaires du Crétacé figurés par d'Orbigny, deuxième partie—Cheilostomata": Bull. Soc. Géol. France, ser. III, vol. xxviii, p. 459, 1900. Cenomanian.

? non *Hippothoa simplex*, d'Orb.: Jukes-Browne & White, *The Geology of the Country around Henley-on-Thames and Wallingford*: Mem. Geol. Surv. Engl. and Wales, 1908, p. 56. *M. coranguinum* zone: Henley district.

Distribution.—Cenomanian: Sarthe.

DACRYOPORA GUTTA,[1] n.sp. (Pl. XXXIV, Figs. 4, 5.)

Diagnosis.—*Dacryopora* with very long fine caudæ, and capitula that are somewhat parallel-sided; extra-terminal front wall very flat, tending to spread out on the incrusted surface; termen with a pair of small spines on the distal edge of the aperture and another pair at the proximal-lateral corners; intra-terminal front wall well arched, sometimes, in addition, somewhat flattened laterally, often showing a median ridge and in some zoœcia a median crack or groove; aperture small, about one-fifth as long as the capitulum, semicircular or very slightly cribrilinid; sealed zoœcia absent or rare.

Type-specimen.—British Museum specimen D. 27932; Senonian, zone of *Micraster cortestudinarium*. Pit west of large pit on Offham Hill, Lewes. C. P. Gaster Coll.

Distribution.—Senonian, zone of *M. cortestudinarium*. Luton, south-east of Chatham, Kent; in the collection of Dr. Rowe, of Margate. Pit west of large pit on Offham Hill, Lewes; B.M. specimens D. 27932, D. 27933; C. P. Gaster Coll. Cliffs between Cuckmere Haven and Hope Gap, Sussex; B.M. specimens D. 27934–41; C. P. Gaster Coll.

Senonian, top of *M. cortestudinarium* zone or base of *M. coranguinum* zone. Chatham, Kent; B.M. specimens D. 11409, D. 27955–63; W. Gamble Coll.

Senonian, zone of *M. coranguinum*. Strood, north-west of Chatham, Kent; in the collection of Dr. Rowe, of Margate.

The above are the only specimens I have seen of what is probably rather a rare form.

DACRYOPORA ELEGANS (d'Orbigny).

Synonymy.

Hippothoa elegans, d'Orb.: d'Orbigny, *Pal. Franç.*, *Terr. Crét.*, vol. v, pl. dccxi, figs. 1–4, 1852; op. cit., p. 384, 1853; op. cit., p. 1092, 1854. Cenomanian: Mans.

H. elegans, d'Orb.: Pictet, *Traité de Pal. . . .*, 2nd ed., vol. iv, p. 103, pl. xc, fig. 8, 1857; Cenomanian. [Figure is a copy of d'Orb., pl. dccxi, figs. 1–2.]

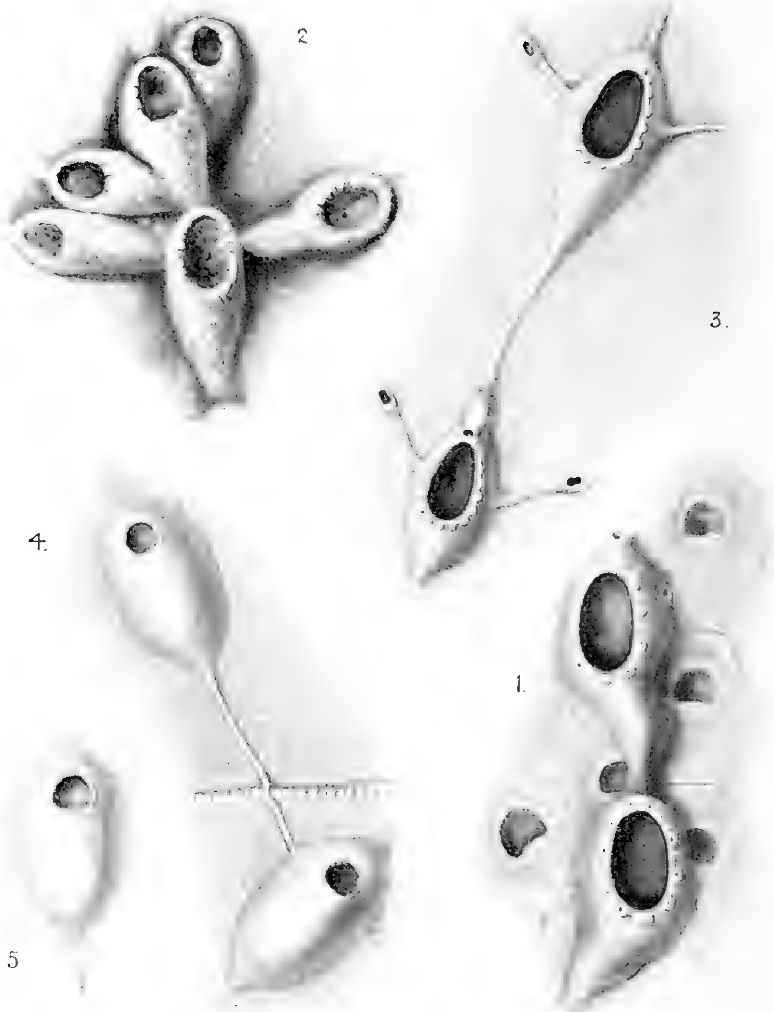
H. elegans: Manzoni, Sitz. d. K. Akad. Wiss. Wien, vol. lxi, pt. i, p. 329, 1870. Cretaceous.

H. elegans, d'Orb.: Vine, Quart. Journ. Geol. Soc., vol. xlvi, p. 484, 1890.

non *Membranipora* (*Hippothoa*) *elegans*, d'Orb.: Gamble, *Supplementary List of the Bryozoa of the Chatham Chalk*, p. 5, 1896. Lower Senonian: Chatham. [A specimen labelled by Gamble as the *Hippothoa elegans* of his list published in 1896 is a *Stomatopora*.]

Diazeuxia elegans (d'Orb.): Canu, "Revision des Bryozoaires du Crétacé figurés par d'Orbigny, deuxième partie—Cheilostomata": Bull. Soc. Géol. France, ser. III, vol. xxviii, p. 459, 1900.

[1] *gutta*, 'a drop'—an echo of the generic name.



G. M. Woodward del.

Cretaceous Cheilostome Polyzoa.

Allantopora, Marssonopora, Dacryopora.

? non *Membranipora* (*Hippothoa*) *elegans*, d'Orb. : Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. iii, The Upper Chalk of England (Mem. Geol. Surv. United Kingdom), p. 491, 1904. *M. cortestudinarium* zone : Charlton.

Distribution.—Cenomanian : Le Mans, Sarthe, France.

Remarks.—The aperture in d'Orbigny's figure appears to be circular, as it does in Reuss' figure of *Escharina dispersa.* These two species are here provisionally placed in *Dacryopora* on the assumption that the apertures are subcircular or semicircular, with a tendency to a cribrilinid shape.

DACRYOPORA REUSSI, new name.

Synonymy.

Escharina dispersa (v. Hagenow): Reuss, *Die Versteinerungen der Böhmischen Kreideformation*, pt. ii, p. 67, pl. xv, fig. 26, 1846. Lower Plänerkalk : Schillinge, bei Bilin, Bohemia.

non *Cellepora dispersa*: Hagenow, *Neues Jahrbuch, Jahrg.* 1839, p. 280 ; Rügen.

Escharina dispersa, Reuss : Bronn, *Index Palæontologicus* . . . A. Nomenclator Palæontologicus, p. 472, 1848.

E. dispersa, Reuss : Bronn, *Index Palæontologicus* . . . B. Enumerator Palæontologicus, p. 131, 1849 ; Kreide.

Pyripora [*Escharina*] *dispersa*, Reuss : d'Orbigny, *Prodrome de Pal.* . . , vol. ii, p. 263, 1850. Senonian : Bilin, Bohemia.

? *Escharina dispersa*, Reuss : Morris, *A Catalogue of British Fossils*, 2nd ed., p. 123, 1854. Chalk detritus : Charing, Kent ; Harris Coll.

? *Microporella dispersa*, Reuss : Vine, Proc. Yorks. Geol. Soc., vol. xi, pt. ii, p. 259, 1890. Upper Greensand : *fide* Morris, 1854.

? *Escharina dispersa*, Reuss : Vine, Rep. Brit. Assoc. 1890, p. 391, 1891. Chalk detritus: Charing, Kent ; *fide* Morris, 1854.

? *E. dispersa*, Reuss : Vine, Proc. Yorks. Geol. Soc., N.S., vol. xii, pt. ii, p. 158, 1892. Chalk detritus : Charing, Kent ; *fide* Morris, 1854.

Distribution.—Cenomanian, Lower Plänerkalk : Schillinge, near Bilin, Bohemia.

Remarks.—See under *D. elegans* (d'Orbigny).

Key to the Genera described in this Paper, including Herpetopora.

A. Calcareous portion of intra-terminal front wall confined to a narrow bevel.
  - I. No avicularia present.
    - *a.* Termen plain . . . . . . *Herpetopora.*
    - *b.* Termen beaded . . . . . *Allantopora.*
  - II. Avicularia present; termen beaded . *Marssonopora.*

B. Intra-terminal front wall entirely calcareous . *Dacryopora.*

EXPLANATION OF PLATE XXXIV.

FIG.

1. *Allantopora irregularis* (Gabb & Horn). Two zoœcia of a zoarium encrusting *Coscinopleura digitata* (Morton). × about 35 diameters. British Museum specimen No. D. 19186. Danian, Vincentown, Limesand. Near Blackwoods Town, New Jersey, U.S.A.
2. *Allantopora stomatoporoides*, n.sp. A piece of zoarium showing bilateral branching which is somewhat irregular in the more distal zoœcium. × about 35 diameters. The type-specimen ; British Museum specimen No. D. 9110. Danian. Faxe, Seeland, Denmark. Caroline Birley Coll. The poor preservation of the specimen, which is of a crystalline, granular consistency, makes it impossible to show greater detail.

FIG.

3. *Marssonopora dispersa* (Hagenow). A piece of a zoarium showing bilateral branching and consisting of two normal zoœcia and the caudal ends of five others, three of which bear small avicularia. The lower normal zoœcium (of which the capitular end only is shown) bears an ovicell. × about 43 diameters. British Museum specimen No. D. 11498. Senonian, zone of *Belemnitella mucronata*. Rügen I., German Baltic.
4. *Dacryopora gutta*, n.sp. A piece of zoarium showing bilateral branching and consisting of two zoœcia, encrusting a piece of shell of *Inoceramus lamarckii*, Parkinson. The caudal portion of one zoœcium traverses a ridge in the shell and consequently appears wavy. × about 33 diameters. British Museum specimen D. 27955. Senonian, top of zone of *Micraster cortestudinarium* or base of zone of *M. coranguinum*, Chatham, Kent. W. Gamble Coll.
5. *Dacryopora gutta*, n.sp. A single zoœcium from the type-specimen × about 37 diameters. British Museum specimen D. 27932. Senonian, zone of *Micraster cortestudinarium*. Pit west of large pit on Offham Hill, Lewes, Sussex. C. T. Gaster Coll.

III.—SAURISCHIA AND ORNITHISCHIA.

By Dr. F. HUENE.

IN 1888 the late Professor H. G. Seeley pointed out for the first time (Rep. Brit. Assoc. Adv. Sci., 1888, pp. 698–9) that Owens' order 'Dinosauria' should be divided into two great natural groups, especially on account of their pelvis. He called them Saurischia (= 'Theropoda' + 'Sauropoda') and Ornithischia (= 'Orthopoda'). He maintained his classification until his death in 1909, but nobody followed him. Only in 1907 did the present writer accept this classification and gave new evidences for it, but still was of opinion that these two groups only were ramifications of one natural unity, the 'Dinosauria'. But now, for several years, the writer has come to the conclusion that the 'Dinosauria' are not of monophyletic origin, but have developed from different points, and should therefore be considered as two distinct natural orders. Superficial similarities have been valued too highly, such as general form and size of the body, bipedal locomotion in two large groups, certain similarities in the formation of the foot, the femur, the humerus, and the shoulder-girdle.

The most striking difference between the Saurischia and the Ornithischia is in the pelvis, as is now generally well known. Even in their oldest known representatives there is no convergence at all in this respect. In the Ornithischia the facial part of the skull is prolonged and without præorbital openings, except in the most primitive forms with a very small fenestra; the dentition is multiplied and specialized; the extremities of the jaws are toothless (except in the primitive *Hypsilophodon*), and in the lower jaw (in one group also in the upper jaw) a new symphysial bone has been formed; the præmaxilla is of enormous size, its posterior extremity being intercalated between maxilla and nasal, and even reaching the lacrymal or the adlacrymal; the internal bony nasal openings are of enormous size, and the formation of the rest of the palate is characteristic; the processus coronoideus in the lower jaw is high, the quadrate is free; and the supraorbital forms part of the roof of the skull (as shown by the writer in the Stegosauria, the Trachodontidæ, and the Ceratopsia). All of these features in the skull are differences from the Saurischia and at the same time show the higher adaptation and specialization of the Ornithischia. So long ago as 1908 the writer stated that no Ornithischia are known in the same primitive stage as certain of the oldest Saurischia.

In the vertebral column Saurischia of the highest specialization do not possess ossified tendons as do all bipedal Ornithischia, even the relatively primitive *Hypsilophodon.* This must be due to a different manner of locomotion and of feeding; the different kind of motion must have the same reason as the transformation of the pelvis and its stronger fixation to the vertebral column. Moreover, abdominal ribs are not yet known in Ornithischia, but they occur in Saurischia even in some of their latest forms.

In a recent paper[1] the writer has tried to demonstrate that the Saurischia and the Ornithischia came from the Pseudosuchia,[2] the former from their most primitive representatives by minor specializations, the latter from more specialized Pseudosuchians by a stage of bipedal hopping creatures in which the pelvis became adapted to this new locomotion by retroversion of the pubis and development of a prepubis. From this stage, as the writer suggests, the birds were also adapted for climbing on trees, then becoming capable of a parachute-flight, in consequence of this acquiring feathers and then later learning true flight (Abel's ideas combined with the writer's).

The name 'Dinosauria' should be absolutely abandoned, as is the case, for instance, with that of 'Enaliosauria'.

In 1908 the writer showed that the Sauropoda must have developed from the Plateosauridæ, an opinion he still retains, although some minor changes in our knowledge of the Saurischia have taken place. The writer now proposes two great sub-orders within the Saurischia: Cœlurosauria and Pachypodosauria (see *Centralbl. f. Min.*, etc., 1914, pp. 154–8), the former with four families: Hallopoda, Podokesauridæ (*Podokesaurus*, *Procompsognathus*, *Saltopus*, *Cœlophysis*, *Tanystrophæus*), Compsognathidæ, Cœluria (incl. *Ornithomimus*); the second sub-order would comprise again two lines of development, one leading from *Thecodontosaurus* to the Plateosauridæ and Sauropoda, the other from *Palæosaurus* to the Megalosauridæ.

IV.—On a Boring at Marston near Devizes.

By A. J. Jukes-Browne, F.R.S., F.G.S. (deceased).

THIS boring, though confined to the Kimeridge Clay, is of some interest, partly because it has proved the thickness of that clay to be much greater than it was supposed to be in this part of Wiltshire, and partly because it has yielded a species of *Aporrhais* or *Harpagodes* which has not previously been found in England.

[1] "Beiträge zur Geschichte der Archosaurier": Geol. u. Pal., Abh. 1914.

[2] Dr. G. A. Boulenger and Mr. D. M. S. Watson propose to reintroduce Owen's term 'Thecodontia', but the types on which he erected this order are: *Stagonolepis*, *Belodon*, *Cladyodon*, *Thecodontosaurus*, *Palæosaurus*, and *Bathygnathus*. They belong to very different orders.

The Kimeridge Clay is believed to be about 300 feet thick at Swindon, and the same thickness is assigned to it in the Index to Sheet 282 of the Geological Survey map, Devizes being about 20 miles south of Swindon. In the memoir on the *Country around Devizes* I did not venture to suggest any thickness for the Kimeridge Clay, of which only a small area comes within the limits of the sheet, and I was not responsible for the Index on the colour-printed edition of 1905, nor for the horizontal section at the foot of that map, which exaggerates the slight syncline that exists below Wotton and Pottern, and also seems to bring the base of the Kimeridge Clay too near the surface under Seend Hill, probably in order to make the position of its base agree with the assumed thickness of 300 feet.

The village of Marston is about 3½ miles south-west of Devizes, and the site of the boring is at Manor Farm, near the cross-roads, where the level of the ground is marked as 176 feet above O.D. The base of the Portland Sands comes in about three-quarters of a mile to the south-east, at a level of about 210 feet, and as the strata must be nearly horizontal near Marston the top of the boring will be about 34 feet below the summit of the Kimeridge Clay.

The boring had been carried to a depth of 180 feet before I was consulted about the prospect of finding water, and Messrs. J. W. Titt and Co. of Warminster were the engineers and contractors. In advising the continuance of the boring I certainly expected that the base of the Kimeridge Clay would be reached at a less depth than 400 feet, and there is every reason to suppose that the underlying Corallian limestones would furnish a plentiful supply of water when they were reached. Unfortunately the Clay has proved to be thicker than was expected, and as there was no sign of nearing its base at 400 feet the proprietor could not be induced to proceed farther in the attempt, so that the boring was abandoned at 412 feet.[1]

No samples were taken from the upper part of the boring down to about 150 feet, and all the information that Messrs. Titt could give me was that the material passed through varied very little and was similar to a sample sent from about 154 feet, which is a sandy grey clay, the sand being of very fine grain.

Between 154 and 157 feet there seems to have been a bed of very sandy clay or clayey sand, for the sample sent leaves when washed a large residue of sand, which consists almost entirely of quartz-grains, rounded or subangular, partly very small and partly of larger but even-sized grains, with only a few pieces of calcite, which may be worn shell-fragments. No Foraminifera could be seen. Another sample from about 165 feet is a similar dark-grey sandy clay, but between that and 167 feet there seems to have been a bed containing small fragments of stone. The sample yielded a large residue of sand, consisting mainly of subangular quartz-grains varying in size from the finest sand to grains of more than a millimetre in diameter; in this sand were some fragments of calcite,

[1] The apparent discrepancy between 400 and 412 feet is due to the fact that the Contractor bored an additional depth of 12 feet at his own cost.

many pieces of shell, and many fragments of dark-grey, compact, fine-grained siliceous grit, one of which was 7 mm. across; there were also a few black grains which may be glauconite.

The next sample from between 167 and 180 feet is also a very sandy clay, but the sand grains are less unequal in size. It also contained several small fragments of the same dark siliceous rock, but these have probably come from above and have been forced into the sample by the boring tool.

At 207 feet there is stiff but still somewhat sandy clay. At 219 feet they struck a spring of water which rose to within 12 feet of the surface, but there was no bed of rock, and the sample sent from that depth is an ordinary clay with some shell-fragments, but less sandy matter than in that from 207 feet. The water must have been flowing down an open crack of some kind, possibly the plane of a fault, but it was easily shut out and the boring was continued. A sample from 220 feet was a fine rather sandy clay with many thin friable fragments of nacreous Ammonite shells.

A sample from 248 feet is a fine clean clay with little sand and of a dark-grey colour; 20 feet lower, at 268 feet, the sample shows a mixture of two different clays, one clean and dark grey, the other a light-grey finely granular marl or calcareous clay. The material was stated to be very soft and to be of the same consistency for a thickness of $2\frac{1}{2}$ feet, but there must have been two distinct beds, or at any rate a band of marl. When a piece of the latter was washed, it would not wholly break down and very little mud could be washed out of it, the residue consisting of hard angular fragments of marl with a few black grains and minute scales of mica; there were no quartz-grains and no Foraminifera, but a few fragments of shell. A sample from a little lower down (272 feet) is a stiff dark-grey clay full of pieces of crushed Ammonite shells.

The sample from 300 feet is specially interesting, because it contains several specimens of an *Aporrhais* or *Harpagodes*, one of which is fairly perfect though flattened out. It has been examined by Mr. R. B. Newton, of the British Museum, who told me that it closely resembled the *Ap. intermedius* [*sic*] of Piette from the Upper Kimeridgian or Virgulian of the Haute Marne.[1] Having also myself compared the specimen with Piette's figures, I think there can be no doubt that the fossil is *Ap. intermedia*, for not only is it of about the same size and carries four keels which are prolonged into digitations of the expanded wing, but the first whorl of the spire has the same shell-structure of vertical ribs crossed by raised spiral striæ, so that it cannot be the young of *Harpagodes oceani*, though it appears to belong to the genus *Harpagodes* rather than to *Aporrhais*. This species has not previously been recorded from England, and is important stratigraphically because it is only known in the Virgulian, and consequently it indicates that the boring at 300 feet is still in the Virgulian or upper division of the stage.

At 304 feet a sample showed fine sandy clay with many fragments of crushed bivalve shells, among which I recognize a piece of

[1] Mém. Soc. Linn. Normandie, vol. xvi, p. 140, pl. ix, figs. 15–17, 1872.

Cardium striatulum, Sow. With the sample was a piece of flint, and the foreman in charge reported that the tool had passed through a layer of stone. If the flint was supposed to be a sample of the layer of stone, it is obvious that there was no such layer and that the flint had fallen down the bore from the surface. This illustrates how mistaken records of stone layers may get into contractors' accounts of borings.

A sample from 314 feet is a stiff grey clay with little or no sand and does not contain any recognizable fossils. The next sample was from 355 feet and is a somewhat shaly clay of a medium-grey tint; it contains a few fragments of small shells.

No more samples were sent till a depth of 400 feet was reached, the statement then being that the clay had continued to be similar to that sent from 355 feet, but the sample from 400 feet was different, being a compact homogeneous dark-grey clay, cutting like cheese, as if there was much organic matter in the material. At 412 feet the clay was again different, being lighter in colour, not of a cheesy texture, but full of small shell-fragments.

From the facts above recorded I think we may conclude that the upper (Virgulian) division extends to at least a depth of 304 feet, and as about 34 feet must be added at the top the total thickness of this division must be at least 338 feet, and probably a few feet more. The clays at and below 350 feet in the boring probably belong to the Pterocerian or Lower Kimeridge, and the question is how much more of the lower division is likely to exist in this part of Wiltshire. I can only see one way of attempting to solve this question, and that is to assume that the proportional thicknesses of the upper and lower divisions are the same as those of the two divisions in Dorset. In 1880 Blake published a diagram drawn to scale of the relative thicknesses of the several parts of the Kimeridge Clay at Kimeridge.[1] This showed a total of 1,000 feet, and assigned a thickness of about 420 feet to the lower division. Strahan, however, in discussing the thickness of the Upper Kimeridge,[2] took the boundary-line between it and the Portland Sands 100 feet higher than Blake did, which makes the total 1,100 feet and the thickness of the Virgulian about 680 feet. Hence in Dorset the latter forms nearly three-fifths of the whole stage. If, therefore, the proportions are the same in South Wilts, and if we assume the Virgulian to be 340 feet thick at Marston, then the thickness of the Pterocerian will be 205 feet and the total 545 feet.

The importance of this boring is that it has proved the thickness of the Kimeridge Clay near Devizes to be more than 446 feet, and has afforded a basis for making a rough calculation of the probable total thickness of the Clay in that district. It is a great pity that no fund exists from which assistance could be obtained for continuing trial borings of this kind, so that some definite result should be obtained, and the expense incurred by the owner of the property should not be entirely wasted.

[1] Quart. Journ. Geol. Soc., vol. xxxvi, p. 197, 1880.
[2] *Geology of the Isle of Purbeck, etc.* (Mem. Geol. Surv.), 1898, p. 52.

V.—The Zone of *Offaster pilula* in the South English Chalk.

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

(*Continued from p. 411.*)

III. Dorset.

THERE are three exposures of the horizon of the zone of *O. pilula* on the Dorset coast—at Ballard Head, Arish Mell, and Middle Bottom. Dr. Rowe's description of the Ballard Head section is so unattractive, and the section itself so inconvenient for access and study, that I put it aside to be attempted only if I had time to spare after working out the others, which has not yet happened. Of the other two, that at (or rather under) Middle Bottom is so much the better that I take it first.

A. *Middle Bottom (between White Nothe and Lulworth).*

As is well known from Dr. Rowe's works,[1] the bay at the head of which is Middle Bottom provides a section in chalk lying above the zone of *Marsupites* and having an accessible thickness of about 200 feet, the point at which the highest beds are accessible being under Middle Bottom itself. At this point the beds are apparently flat in all directions, and I did not notice anything about them which I could reconcile with Dr. Rowe's description of them as "riven and shattered in every direction". For some distance westwards from the recess under Middle Bottom the beds seem to continue flat, but an easterly dip (apparently only a component of a stronger S.S.E. dip) then sets in and brings up the beds below in regular succession. The sequence measured was as follows :—

Highest Flint Seam in Reach in the Recess under Middle Bottom.

		ft.	in.	ft.	in.
Zone of *A. quadratus*.	Chalk	8	0		
	Strong flint seam (apparently the one mentioned by Dr. Rowe).				
	Chalk with one *A. quadratus*	4	0		
	Weak flint seam.				
	Chalk	30	0		
	Strong yellowish marl seam.				
	Chalk	2	6		
	Marl seam.				
	Chalk	12	0		
	Parting probably representing a marl seam.				
	Chalk	3	0		
	Flint seam.				
	Chalk	1	0		
	Carried forward . .			60	6

[1] *Coast Sections*, II, pp. 11–13.

Zone	Subzone	Belt	Bed	ft.	in.	ft.	in.
			Brought forward . .			60	6
			Strong marl seam, very yellow.				
Zone of *O. pilula.*	Subzone of abundant *O. pilula.*	Upper belt of *O. pilula.*	Chalk with *O. pilula* of exceptional size .	1	6		
			Flint seam.				
			Chalk with large *O. pilula*	1	6		
			Marl seam.				
			Chalk with *O. pilula*	18	0		
			Marl seam.				
		Cinctus belt.	Chalk without marl seams. No *O. pilula* observed	48	0		
		Lower belt of *O. pilula.*	Chalk with *O. pilula*, stretching 5 feet above and 10 feet below a parting. No marl seams or definite flint seams . . .	15	0		
				——		84	0
			Strong flint seam.				
	Subzone of *E. scutatus*, var. *depressus.*		Chalk	16	0		
			Weak marl seam.				
			Chalk	1	0		
			Strong marl seam.				
			Chalk	27	0		
			Indications of a marl seam.				
			Chalk with perhaps a slide plane at its base	8	6		
				——		52	6
Zone of *Marsupites.*			Chalk, very confused and doubtful, perhaps bounded both above and below by slide planes	10	0		
			Chalk	9	0		
			Flinty chalk, yielding *Marsupites* . .	2	0		
			Chalk	6	6		
			Flint tabular.				
			Chalk with *Marsupites* in lower part . .	6	0		
				——		33	6
			Marl seam and parting.				
Uintacrinus band.			Chalk with *Uintacrinus* at base . . .			63	0
						293	6
			Marl seam and parting.				

The subzone of abundant *O. pilula* is easily recognizable here in its broad features and capable of definite measurement. Closer search than I had time to make would probably enable more of its minor features to be supplied, seeing how closely the lithological and palæontological details at its top coincide with those noted in the same position in Hants, Sussex, and the Isle of Wight. It might also be possible to identify some of the characteristics of the subzone of *Echinocorys scutatus*, var. *depressus*, although the section becomes very unfavourable by the time this horizon is reached. I have taken as the boundary between my zones of *O. pilula* and *Marsupites* the level at which, calculating from the lower boundary of his *Marsupites* band, which can be identified with practical certainty, Dr. Rowe found his highest plate of *Marsupites*. My own finds of *Marsupites* did not carry it outside these limits.

The thickness Dr. Rowe assigns by measurement to the combined zones of *O. pilula* and *A. quadratus* is 204 feet. My corresponding measurement is 189 feet, a very near agreement under the circumstances.

All the marl seams which were noticed have been recorded in the above section. There are in addition a few partings, all of which suggest that they have opened along thin marl seams, the marl of which has been washed away or bleached beyond recognition. But even crediting all these partings as actual marl seams, the paucity of marl seams is very striking when their abundance in the Sussex and Isle of Wight sections is considered.

I did not observe evidence of sliding along the parting which marks the base of the zone of *Marsupites*. In the upper part of the cliff the parting appeared to correspond with the bedding and to be an opening along a marl seam, in which case sliding, if it took place, would leave no clear evidence. When the parting left this marl seam close to the foot of the cliff and curved across the flint seams it did not seem to shift them, as must be the case if there had been sliding along it.

On the east side of the recess under Middle Bottom the cliff line runs out to high-water mark and then turns again east and the beds oscillate slightly without any effective dip for a considerable distance; a further 6 feet of chalk becomes thus measurable, making a measured total of 67 feet of *quadratus* chalk. The westward dip which then sets in and increases rapidly gives a downward section which is practically undisturbed down to the top beds of the zone of *O. pilula*, and these beds agree exactly in thickness with the corresponding beds on the other side of the syncline. Beyond this point the chalk becomes almost immediately too disturbed for reliable measurement.

I am strongly disposed to think that if there is any actual dislocation in this neighbourhood corresponding to the Purbeck fault, it is not a fault but is dissipated into one or more slides along the highly inclined bedding planes of the chalk between the zones of *A. quadratus* and *M. cor-anguinum*, the precise plane or planes of sliding being determined by the lines of weakness offered by marl seams. There are several wide partings at beach level, and one or two at any rate seemed to correspond with marl seams on the other side of Middle Bottom.

B. *Arish Mell.*

This is a most disappointing locality, for it might fairly be hoped that its two sides would between them give a complete section of the zones of *O. pilula* and *A. quadratus*, whereas they do not give a complete recognizable section of either. The accompanying map will aid identification of the various points referred to in the description; the outline given for the base of the cliff is intended to represent beach level under summer conditions.

1. *East side.*—This is another case in which Dr. Rowe does not give any reliable clue for re-identifying the zonal boundaries he adopted. The following section will serve the same purpose as the Scratchells Bay section, of giving subsequent explorers the use of my finds. The crushed flint seam close to the top of the *Uintacrinus* band is easily recognized, and most of the other points can be individually identified.

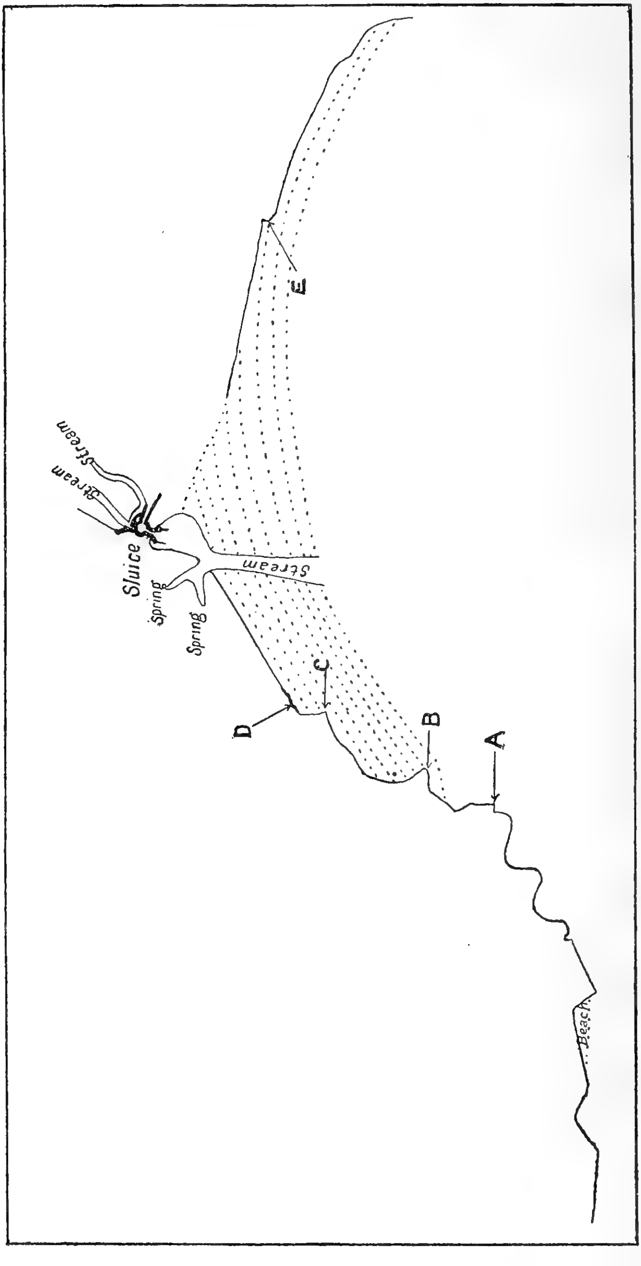


FIG. 1. Ground-plan of cliffs and banks in Arish Mell.

RUBBLY CHALK NEARLY ALL RECONSTRUCTED.

Zone	Subzone	Bed	ft.	in.	ft.	in.
		Strong marl seam in recess.				
Zone of *O. pilula* (incomplete).	Subzone of abundant *O. pilula.*	Chalk with three marl seams, embracing the sharp corner E	16	6		
		Marl seam.				
		Chalk with *O. pilula* and three marl seams, embracing the blunt corner, the lower part strongly veined and honeycombed with calcite	7	9		
					24	3
		Marl seam wide open.				
	Subzone of *E. scutatus,* var. *depressus.*	Chalk with three marl seams, one of them open	16	6		
		Marl seam.				
		Chalk	14	6		
		Marl seam cut by slide plane 3 feet above beach.				
		Chalk with one marl seam	12	6		
		Thick marl seam.				
		Chalk	1	0		
		Marl seam.				
		Chalk	6	3		
					50	9
		Flint seam.				
Zone of *Marsupites.*		Chalk with *Marsupites* in highest bed	14	6		
		Very thick marl seam cut by slide plane about 4 feet above beach.				
		Chalk with four marl seams and *Marsupites* in lowest bed	14	6		
		Flint seam.				
		Chalk without *Marsupites* or *Uintacrinus*	3	6		
					32	6
		Marl seam.				
Uintacrinus band.		Chalk without *Uintacrinus* or *Marsupites*	2	6		
		Flint seam.				
		Chalk with *Uintacrinus*	1	6		
		Thick seam of crushed flint cut by slide plane about 8 feet above beach.				
		Chalk	1	0		
		Marl seam.				
		Chalk	16	3		
		Marl seam.				
		Chalk with *Uintacrinus* brachials	6	6		
					27	9
		Marl seam.				

The boundaries taken for the zone of *Marsupites* and the *Uintacrinus* band are of course tentative; the combined thickness of 60 feet assigned to them is obviously a minimum, and may prove to be considerably within the mark. The marl seam taken as the base of the *Uintacrinus* band is the last in descending order for some way; there are two, one thin and one thick, close together a little west of the rain-water gully and one a little beyond it, and then the *cor-anguinum* chalk finally asserts its usual marlless character. The resemblance between this sequence and the corresponding one at Scratchells Bay is striking.

It will be seen that 51 feet above the highest point to which I have traced *Marsupites* an unmistakable representative of the subzone of abundant *O. pilula* makes its appearance, at least six specimens of *O. pilula* having been observed in a thickness of 7 feet of almost vertical chalk of most unpromising character. Above this point there is only about 22 feet of chalk *in situ*, and it is very unlikely that any representative of the upper belt of *O. pilula* will be identified on this side of the bay. A specimen of *Bourgueticrinus* Form 5 was found a few feet below the belt with *O. pilula*, a normal position for it.

2. *West side.*—The west side of Arish Mell, strictly speaking, runs from the stream to the corner A, at which the vertical chalk comes to an end; but each of the three small sloping promontories immediately succeeding this corner contributes a little more to the thickness of chalk passed over, and they are therefore included.

It will be seen that from the corner A northwards the outline divides itself naturally into three bays. The first runs up to a little above the lowest beach level at corner B; the second runs up to approximately high-water mark at corner C, and its sides are more or less wave-beaten the whole way; and the third runs in a practically straight line to an angle which marks, broadly speaking, the end of the west side of Arish Mell, and thence again in a practically straight line to the stream. About 10 feet east of this angle in the third bay there is a low cascade (D) leading up to a deep hole some 4 feet above the beach level. In winter a stream breaks out either from this hole, running down the cascade, or at the foot of the cascade. The cascade forms an excellent landmark, and starting from a flint seam which crosses the cascade just below its top, and is the highest that can be definitely identified, I measured the following section seaward:—

	ft.	in.
Chalk	11	6
Flint seam lining a south face extending west from the cascade.		
Chalk with *A. quadratus* at top	4	0
String of large flints.		
Chalk	28	0
Last flint seam north of angle C.		
Chalk without flints embracing angle C	8	6
Flint seam.		
Chalk	74	0
Stringy marl seam.		
Chalk	16	6
Thick marl seam.		
Chalk forming ridge at angle B	2	6
Thick marl seam.		
Chalk	2	6
Strong parting.		
Chalk	8	0
Marl seam.		
Chalk	14	6
Flint seam crossing recess.		
Chalk with giant ossicle of *Metopaster Parkinsoni* . . .	6	6
Flint seam at end of clean chalk.		
Chalk	17	9
Strong marl seam.		
Chalk	1	6
Marl seam.		
Carried forward . . .	195	9

	ft.	in.
Brought forward . .	195	9
Chalk	2	0
Marl seam.		
Chalk	16	9
Marl seam.		
Chalk	2	9
Marl seam passing just south of angle A.		
Chalk with three marl seams	16	8
Marl seam.		
Chalk with *Terebratulina Rowei*, presumably in subzone of abundant *O. pilula*	7	0
Marl seam.		
Chalk with three marl seams	22	0
Marl seam.		
Chalk, perhaps basement bed of subzone of abundant *O. pilula*	1	0
Marl seam.		
Chalk with *E. scutatus*, var. *depressus*, and rectangular *Crateraster quinqueloba*, forming strongly marked face in the third promontory	6	0
Marl seam.		
Chalk with one marl seam	3	8
Marl seam.		
Chalk	16	6
Marl seam.		
Chalk to extreme foot of third promontory	9	0
	299	1

My starting-point was probably in *quadratus* chalk, as I found a specimen of *A. quadratus* about 12 feet below it on my first visit. The specimen was partly exposed by weathering, and the granulations on it were plainly visible to the naked eye. I exposed its full length and left it there as a landmark, in the hope that it would escape the mere curiosity hunter, and it was still there at my latest visit. For a distance of about 180 feet the chalk was more or less capable of examination, and it could be said with fair certainty that the zone of *O. pilula* had not been reached, though the giant ossicle of *Metopaster Parkinsoni* found in the last few feet hinted at the approach of that zone. Beyond this point the cliff was vertical and wholly obscured and the foreshore little better, and I reached the corner A without seeing any sign of the zone of *O. pilula*. In the promontories west of corner A I was able to identify fairly satisfactorily both the subzone of abundant *O. pilula* (apparently the lower belt of *O. pilula*) and the subzone of *E. scutatus*, var. *depressus*. The individual beds were not at all easy to follow, but those in which I detected the fauna of the subzone of abundant *O. pilula* seemed to pass just south of corner A, so that the upper boundary of this subzone (and of the zone of *O. pilula*) probably passes through the wholly obscured part of the Arish Mell cliff.

Beyond the third promontory the cliff is cut sharply back into the subzone of abundant *O. pilula*, probably as far as the middle belt and possibly at one point into the upper belt of *O. pilula*. The surface is so irregular and the beds so much affected by compression and probable faulting that I could not satisfy myself that they could be followed accurately enough for more positive identification, or for any attempt at measuring the thickness down to the zone of *Marsupites* at the west end of Cockpit Head.

Returning to my starting-point, the cascade, it is pretty clear that up to the angle just west of it the cliff is wholly composed of chalk *in situ*. But at this angle the upper part of the cliff at once begins to bear a rubbly appearance, which at the cascade has extended some way down the cliff, and within 20 feet west of the cascade the cliff, now more a bank than a cliff in the ordinary sense, becomes definitely alluvial almost to the bottom. There is chalk washed clean at its foot all the way to the stream, but even close to the cascade this chalk had a very boulder-like appearance, and for the greater part of the way it seems clearly to be composed of loose blocks in an alluvial setting. Certainly there is no chalk between the cascade and the stream which looks likely to be *in situ*. Much of the chalk above the cascade and between it and the stream is noticeably softer than any chalk in Arish Mell which is undoubtedly *in situ*.

I find it difficult to reconcile this state of things with Dr. Rowe's description. In the first place we seem to be largely at variance as to the thickness of his *quadratus* zone. His description does not afford any means of accurately identifying the point at which he placed its upper boundary, but from a careful study of his plate VI on the ground it appears to be just about the cascade. This is confirmed by the cascade being as nearly as possible 182 feet from the stream where it cuts the line of the bay. (Dr. Rowe speaks of his starting-point as being about 182 feet from the 'sluice', but he must have intended to write 'stream', for the sluice is much more than 182 feet from any point that can be reconciled with the indications given.) It is therefore probable that we adopted practically the same starting-point, but Dr. Rowe gives a thickness of 354 feet for his *quadratus* zone, while I find that 260 feet takes me well into the subzone of *E. scutatus*, var. *depressus*. Even allowing for the rest of this subzone a further 45 feet, which is almost the full thickness of the subzone on the opposite side of Arish Mell, I only get 305 feet for the combined zones of *A. quadratus* and *O. pilula*, the equivalent of Dr. Rowe's *quadratus* zone. This shows a discrepancy of about 50 feet, which is very considerable for a piece of measuring of which the greater part is quite straightforward.

Another point of difficulty lies in Dr. Rowe's account of *mucronata* chalk at the head of the bay. When I first read this account the impression I derived from it was that it recorded a section reaching 182 feet up into the zone of *B. mucronata*; and I relied upon this impression in discussing[1] the probability of *Magas pumilus* ranging down to the base of that zone. Since familiarizing myself with the locality I have read Dr. Rowe's account again very carefully to see whether I had overlooked some other construction which would harmonize better with my own experience, but I am satisfied that I put the natural interpretation on Dr. Rowe's account. He states (p. 29) that there are "about 182 feet of the *B. mucronata* chalk exposed". Similar expressions occurring in abundance throughout his works refer

[1] *The Stratigraphy of the Chalk of Hants*, p. 9.

invariably to thickness of chalk, not length of exposure; and though it is possible that the phrase is here intended to refer to length of exposure, not thickness of chalk, that theory can hardly be reconciled with the contrast he draws (p. 28) between *M. pumilus* found "close to the sluice" and a form of *Echinocorys* found "near the base of the zone". The point is one of some importance, for if the chalk exposed is *in situ* right up to the stream the strike corresponds so nearly with the direction of the bank between the cascade and the stream that not more than 30 feet of chalk at the outside can be brought in in this distance. A specimen of *M. pumilus* found even at the very edge of the stream would then occur practically at the base of the zone, which is completely at variance with all my experience elsewhere; even the 150 feet of *mucronata* chalk in Whitecliff Bay, and the 196 feet in Scratchells Bay have only yet yielded me one specimen each. But if this chalk is not *in situ*, then the occurrence of *M. pumilus* in it is immaterial in considering the downward range of that fossil. Further, if there is no *mucronata* chalk *in situ* at the foot of the cliff Barrois' reference of the chalk of the west side of Arish Mell to his zone of *Marsupites* is not open to the criticism Dr. Rowe levels at it; for it is abundantly clear that Barrois' zone of *Marsupites* embraced the greater part, probably the whole, of the old zone of *A. quadratus*.

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

NOTICES OF MEMOIRS.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AUSTRALIA, AUGUST, 1914.

I.—Address to the Geological Section by Professor Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S. (President of Section C).

(*Concluded from the September Number, p. 418.*)

TO attempt a discussion of the explanations offered to account for the great Upper Palæozoic glaciation would lead us far from the present theme. The question is raised merely to show that the phenomena are not consistent with the supposed movement of a solid shell over a solid core assisted by an intermediate molten lubricant. Geologists may be compelled to hand back the theory of a molten substratum to the mathematicians and physicists for further repair; but it does not necessarily follow that a foundation theory is unsound merely because it has been overloaded beyond its comprehensive strength.

The extraordinarily great distances between the areas that show signs of glaciation in Permo-Carboniferous times form a serious stumbling-block to most of the explanations which have hitherto been offered. One is almost tempted in despair even to ask if it is not possible that these fragments of the old Gondwana continent are now more widely separated from one another than they were in Upper Palæozoic times. It is a bold suggestion indeed that one can safely put aside as absurd in geomorphology. There is nothing else apparently left for us but the assumption of a general refrigeration.

The idea of the greater inequalities of the globe being in approximately static equilibrium has been recognized for many years: it was expressed by Babbage and Herschel; it was included in Archdeacon Pratt's theory of compensation; and it was accepted by Fisher as one of the fundamental facts on which his theory of mountain structure rested. But in 1889 Captain C. E. Dutton presented the idea "in a modified form, in a new dress, and in greater detail"; he gave the idea orthodox baptism and a name, which seems to be necessary for the respectable life of any scientific theory. "For the condition of equilibrium of figure, to which gravitation tends to reduce a planetary body, irrespective of whether it be homogeneous or not," Dutton[1] proposed "the name *isostasy*". The corresponding adjective would be isostatic—the state of balance between the ups and downs on the Earth.

For a long time geologists were forced to content themselves with the conclusion that the folding of strata is the result of the crust collapsing on a cooling and shrinking core; but Fisher pointed out that the amount of radial shrinking could not account even for the present great surface inequalities of the lithosphere, without regard to the enormous lateral shortening indicated by the folds in great mountain regions, some of which, like the Himalayan folds, were formed at a late date in the Earth's history, folds which in date and direction have no genetic relationship to G. H. Darwin's primitive wrinkles. Then, besides the folding and plication of the crust in some areas, we have to account for the undoubted stretching which it has suffered in other places, stretching of a kind indicated by faults so common that they are generally known as normal faults. It has been estimated by Claypole that the folding of the Appalachian Range resulted in a horizontal compression of the strata to a belt less than 65 per cent of the original breadth. According to Heim the diameter of the northern zone of the Central Alps is not more than half the original extension of the strata when they were laid down in horizontal sheets. De la Beche, in his memoir on Devon and Cornwall, which anticipated many problems of more than local interest, pointed out that, if the inclined and folded strata were flattened out again, they would cover far more ground than that to which they are now restricted on the geological map. Thus, according to Dutton, Fisher, and others, the mere contraction of the cooling globe is insufficient to account for our great rock-folds, especially great folds like those of the Alps and the Himalayas, which have been produced in quite late geological times. It is possible that this conclusion is in the main true; but in coming to this conclusion we must give due value to the number of patches which have been let into the old crustal envelope—masses of igneous rock, mineral veins, and hydrated products which have been formed in areas of temporary stretching, and have remained as permanent additions to the crust, increasing the size and bagginess of the old coat, which, since the discovery of radium, is now regarded as much older than was formerly imagined by non-geological members of the scientific world.

The peculiar nature of rock-folds presents also an obstacle no less formidable from a qualitative point of view. If the skin were merely collapsing on its shrinking core we should expect wrinkles in all directions; yet we find great folded areas like the Himalayas stretching continuously for 1,400 miles, with signs of a persistently directed overthrust from the north; or we have folded masses like the Appalachians of a similar order of magnitude stretching from Maine to Georgia, with an unmistakable compression in a north-west to south-east direction. The simple hypothesis of a collapsing crust is thus "quantitatively insufficient", according to Dutton, though this is still doubtful, and it is "qualitatively inapplicable", which is highly probable.

In addition to the facts that rock-folds are maintained over such great distances and that later folds are sometimes found to be superimposed on older ones, geologists have to account for the conditions which permit of the gradual accumulation of enormous thicknesses of strata without corresponding rise of the surface of deposition.

On the other hand, too, in folded regions there are exposures of beds superimposed on one another with a total thickness of many miles more than the height of any known mountain, and one is driven again to conclude that uplift has proceeded *pari passu* with the removal of the load through the erosive work of atmospheric agents.

It does not necessarily follow that these two processes are the direct result of loading in one case and of relief in the other; for slow subsidence gives rise

[1] Dutton, "On some of the Greater Problems of Physical Geology": Bull. Phil. Soc. Washington, vol. xi, p. 53, 1889.

to the conditions that favour deposition and the uplifting of a range results in the increased energy of eroding streams.

Thus there was a natural desire to see if Dutton's theory agreed with the variations of gravity. If the ups and downs are balanced, the apparently large mass of a mountain range ought to be compensated by lightness of material in and below it. Dutton was aware of the fact that this was approximately true regarding the great continental plateau and oceanic depressions; but he imagined that the balance was delicate enough to show up in a small hill-range of 3,000 to 5,000 feet.

The data required to test this theory accumulated during the triangulation of the United States, have been made the subject of an elaborate analysis by J. F. Hayford and W. Bowie.[1] They find that, by adopting the hypothesis of isostatic compensation, the differences between the observed and computed deflections of the vertical caused by topographical inequalities are reduced to less than one-tenth of the mean values which they would have if no isostatic compensation existed. According to the hypothesis adopted, the inequalities of gravity are assumed to die out at some uniform depth, called the depth of compensation, below the mean sea-level. The columns of crust material standing above this horizon vary in length according to the topography, being relatively long in highlands and relatively short under the ocean. The shorter columns are supposed to be composed of denser material, so that the product of the length of each column by its mean density would be the same for all places. It was found that by adopting 122 kilometres as the depth of compensation, the deflection anomalies were most effectually eliminated, but there still remained unexplained residuals or local anomalies of gravity to be accounted for.

Mr. G. K. Gilbert,[2] who was one of the earliest geologists to turn to account Dutton's theory of isostasy, has recently offered a plausible theory to account for these residual discrepancies between the observed deflections and those computed on the assumption of isostatic compensation to a depth of 122 kilometres. An attempt had already been made by Hayford and Bowie to correlate the distribution of anomalies with the main features of the geological map and with local changes in load that have occurred during comparatively recent geological times. For example, they considered the possibility of an increased load in the Lower Mississippi Valley, where there has been in recent times a steady deposition of sediment, and therefore possibly the accumulation of mass slightly in advance of isostatic adjustment. One would expect in such a case that there would be locally shown a slight excess of gravity, but, on the contrary, there is a general prevalence of negative anomalies in this region. In the Appalachian region, on the other hand, where there has been during late geological times continuous erosion, with consequent unloading, one would expect that the gravity values would be lower, as isostatic compensation would naturally lag behind the loss of overburden; this, however, is also not the case, for over a greater part of the Appalachian region the anomalies are of the positive order. Similarly, in the north central region, where there has been since Pleistocene times a removal of a heavy ice-cap, there is still a general prevalence of positive anomalies.

These anomalies must, therefore, remain unexplained by any of the obvious phenomena at the command of the geologist. G. K. Gilbert now suggests that, while it may be true that the product of the length of the unit column by its mean density may be the same, the density variations within the column

[1] J. F. Hayford, "The Figure of the Earth and Isostasy": U.S. Coast and Geodetic Survey, Washington, 1909. "Supplementary Investigation," Washington, 1910. See also *Science*, N.S., vol. xxxiii, p. 199, 1911. J. F. Hayford & W. Bowie, "The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity": U.S. Coast and Geodetic Survey Special Publication No. 10, Washington, 1912.

[2] "Interpretation of Anomalies of Gravity": U.S. Geol. Surv. Professional Paper 85-C, p. 29, 1913.

may be such as to give rise to different effects on the pendulum. If, for instance, one considers two columns of the same size and of exactly the same weight, with, in one case, the heavy material at a high level and in the other case with the heavy material at a low level, the centre of gravity of the former column, being nearer the surface, will manifest itself with a greater pull on the pendulum; these columns would be, however, in isostatic adjustment.[1]

Gilbert's hypothesis thus differs slightly from the conception put forth by Hayford and Bowie; for Gilbert assumes that there is still appreciable heterogeneity in the more deep-seated parts of the Earth, while Hayford and Bowie's hypothesis assumes that in the nuclear mass density anomalies have practically disappeared, and that there is below the depth of compensation an adjustment such as would exist in a mass composed of homogeneous concentric shells.

In order to make the Indian observations comparable to those of the United States as a test of the theory of isostasy, Major H. L. Crosthwait[2] has adopted Hayford's system of computation and has applied it to 102 latitude stations and eighteen longitude stations in India. He finds that the unexplained residuals in India are far more pronounced than they are in the United States, or, in other words, it would appear that isostatic conditions are much more nearly realized in America than in India.

The number of observations considered in India is still too small for the formation of a detailed map of anomalies, but the country can be divided into broad areas which show that the mean anomalies are comparable to those of the United States only over the Indian Peninsula, which, being a mass of rock practically undisturbed since early geological times, may be regarded safely as having approached isostatic equilibrium. To the north of the peninsula three districts form a wide band stretching west-north-westwards from Calcutta, with mean residual anomalies of a positive kind, while to the north of this band lies the Himalayan belt, in which there is always a large negative residual.

Colonel Burrard[3] has considered the Himalayan and sub-Himalayan anomalies in a special memoir, and comes to the conclusion that the gravity deficiency is altogether too great to be due to a simple geosynclinal depression filled with light alluvium such as we generally regard the Gangetic trough to be. He suggests that the rapid change in gravity values near the southern margin of the Himalayan mass can be explained only on the assumption of the existence of a deep and narrow rift in the sub-crust parallel to the general Himalayan axis of folding. A single large rift of the kind and size that Colonel Burrard postulates is a feature for which we have no exact parallel; but one must be careful not to be misled by the use of a term which, while conveying a definite mental impression to a mathematician, appears to be incongruous with our geological experience. There may be no such thing as a single large rift filled with light alluvial material, but it is possible that there may still be a series of deep-seated fissures that might afterwards become filled with mineral matter.

With this conception of a rift or a series of rifts, Colonel Burrard is led to reverse the ordinary mechanical conception of Himalayan folding. Instead now of looking upon the folds as due to an overthrust from the north, he regards

[1] It is interesting to note that the idea suggested by G. K. Gilbert in 1913 was partly anticipated by Major H. L. Crosthwait in 1912 (Survey of India, Professional Paper No. 13, p. 5). Major Crosthwait, in discussing the similar gravity anomalies in India, remarks parenthetically: "Assuming the doctrine of isostasy to hold, is it not possible that in any two columns of matter extending from the surface down to the depth of compensation there may be the same mass, and yet that the density may be very differently distributed in the two columns? These two columns, though in isostatic equilibrium, would act differently on the plumb-line owing to the unequal distribution of mass. The drawback to treating this subject by hard and fast mathematical formulæ is that we are introducing into a discussion of the constitution of the earth's crust a uniform method when, in reality, probably no uniformity exists."

[2] Survey of India, Professional Paper No. 13, 1912.

[3] Ibid., No. 12, 1912.

the corrugations to be the result of an under-creep of the sub-crust towards the north. Thus, according to this view, the Himalaya, instead of being pushed over like a gigantic rock-wave breaking on to the Indian *Horst*, is in reality being dragged away from the old peninsula, the depression between being filled up gradually by the Gangetic alluvium. So far as the purely stratigraphical features are concerned, the effect would be approximately the same whether there is a superficial overthrust of the covering strata or whether there is a deep-seated withdrawal of the basement which is well below the level of observation.

Since the Tibetan expedition of ten years ago we have been in possession of definite facts which show that to the north of the central crystalline axis of the Himalaya there lies a great basin of marine sediments forming a fairly complete record from Palæozoic to Tertiary times, representing the sediments which were laid down in the great central Eurasian ocean to which Suess gave the name *Tethys*. We have thus so far been regarding the central crystalline axis of the Himalaya as approximately coincident with the old northern coast-line of Gondwanaland; but, if Colonel Burrard's ideas be correct, the coastline must have been very much further to the south before the Himalayan folding began.

Representing what the Geological Survey of India regards as the orthodox view, Mr. H. H. Hayden[1] has drawn attention to some conclusions which, from our present geological knowledge, appear to be strange and improbable in Colonel Burrard's conclusions, and he also offers alternative explanations for the admitted geodetic facts. Mr. Hayden suggests, for instance, that the depth of isostatic compensation may be quite different under the Himalayan belt from that under the regions to the south. His assumptions, however, in this respect are, as pointed out by Colonel G. P. Lenox Conyngham,[2] at variance with the whole theory of isostasy. Mr. Hayden then suggests that most of the excessive anomalies would disappear if we took into account the low specific gravity of the sub-Himalayan sands and gravels of Upper Tertiary age as well as of the Pleistocene and recent accumulations of similar material filling the Indo-Gangetic depression. It would not be at all inconsistent with our ideas derived from geology to regard the Gangetic trough as some 3 or 4 miles deep near its northern margin, thinning out gradually towards the undisturbed mass of the Indian Peninsula, and Mr. R. D. Oldham,[3] with this view, has also calculated the effect of such a wedge of alluvial material of low specific gravity, coming to the conclusion that the rapid change in deflection, on passing from the Lower Himalaya southward towards the peninsula, can mainly be explained by the deficiency of mass in the alluvium itself.

It is obvious that, before seeking for any unusual cause for the gravity anomalies, we ought to take into account the effect of this large body of alluvium which lies along the southern foot of the range. It is, however, by no means certain that a thick mass of alluvial material, accumulated slowly and saturated with water largely charged with carbonate of lime, would have a specific gravity so appreciably lower than that of the rocks now exposed in the main mass of the Himalaya as to account for the residual anomalies. Some of the apparent deficiency in gravity is due to this body of alluvium, but it will only be after critical examination of the data and more precise computation that we shall be in a position to say if there is still room to entertain Colonel Burrard's very interesting hypothesis.

By bringing together the geological and geodetic results we notice five roughly parallel bands stretching across Northern India. There is (1) a band of abnormal high gravity lying about 150 miles from the foot of the mountains, detected by the plumb-line and pendulum; (2) the great depression filled by the Gangetic alluvium; (3) the continuous band of Tertiary rock, forming the sub-Himalaya, and separated by a great boundary overthrust from (4) the main

[1] Rec. Geol. Surv. Ind., vol. xliii, pt. ii, p. 138, 1913.
[2] Rec. Surv. Ind., vol. v, p. 1.
[3] Proc. Roy. Soc., ser. A, vol. xc, p. 32, 1914.

mass of the Outer and Central Himalaya of old unfossiliferous rock, with the snow-covered crystalline peaks flanked on the north by (5) the Tibetan basin of highly fossiliferous rocks formed in the great Eurasian mediterranean ocean that persisted up to nearly the end of Mesozoic times.

That these leading features in North India can hardly be without genetic relationship one to another is indicated by the geological history of the area. Till nearly the end of the Mesozoic era the line of crystalline, snow-covered peaks now forming the Central Himalaya was not far from the shore-line between Gondwanaland, stretching away to the south, and Tethys, the great Eurasian ocean. Near the end of Mesozoic times there commenced the great outwelling of the Deccan Trap, the remains of which, after geological ages of erosion, still cover an area of 200,000 square miles, with a thickness in places of nearly 5,000 feet. Immediately after the outflow of this body of basic lava, greater in mass than any known eruption of the kind, the ocean flowed into North-West India and projected an arm eastwards to a little beyond the point at which the Ganges now emerges from the hills. Then followed the folding movements that culminated in the present Himalayan Range, the elevation developing first on the Bengal side, and extending rapidly to the north-west until the folds extended in a great arc for some 1,400 miles from south-east to north-west.

New streams developed on the southern face of the now rising mass, and although the arm of the sea that existed in early Tertiary times became choked with silt, the process of subsidence continued, and the gradually subsiding depression at the foot of the hills as fast as it developed became filled with silt, sand, gravel, and boulders in increasing quantities as the hills became mountains and the range finally reached its present dimensions, surpassing in size all other features of the kind on the face of the globe.

Now, it is important to remember that for ages before the great outburst of Deccan Trap occurred there was a continual unloading of Gondwanaland, and a continual consequent overloading of the ocean bed immediately to the north; that this process went on with a gradual rise on one side and a gradual depression on the other; and that somewhere near and parallel to the boundary line the crust must have been undergoing stresses which resulted in strain, and, as I suggest, the development of those fissures that let loose the floods of Deccan Trap and brought to an end the delicate isostatic balance.

During the secular subsidence of the northern shore-line of Gondwanaland, accompanied by the slow accumulation of sediment near the shore and the gradual filing away of the land above sea-level, there must have been a gradual creep of the crust in a northerly direction. Near the west end of the Himalayan arc this movement would be towards the north-west for a part of the time; at the east end the creep would be towards the north-north-east and north-east. Thus there would be a tendency from well back in Palæozoic times up to the end of the Cretaceous period for normal faults—faults of tension—to develop on the land, with a trend varying from W.S.W.–E.N.E. to W.N.W.–E.S.E. across the northern part of Gondwanaland. We know nothing of the evidence now pigeon-holed below the great mantle of Gangetic alluvium, while the records of the Himalayan region have been masked or destroyed by later foldings. But in the stratified rocks lying just south of the southern margin of the great alluvial belt we find a common tendency for faults to strike in this way across the present peninsula of India. These faults have, for instance, marked out the great belt of coal-fields stretching for some 200 miles from east to west in the Damuda Valley. On this, the east side of India, the fractures of tension have a general trend of W.N.W.–E.S.E. We know that these faults are later than the Permian period, but some of them certainly were not much later.

If we now go westwards across the Central Provinces and Central India and into the eastern part of the Bombay Presidency, we find records of this kind still more strikingly preserved; for where the Gondwana rocks, ranging from Permo-Carboniferous to Liassic in age, rest on the much older Vindhyan Series, we find three main series of these faults. One series was developed before Permo-Carboniferous times; another traverses the Lower Gondwanas, which range up to about the end of Permian times; while the third set affects the younger and Upper Gondwanas of about Rhætic or Liassic age. Although the present topography of the country follows closely the outlines of the geological formations, it is clear from the work of the Geological Survey of India that these outlines were determined in Mesozoic times, and that the movements which formed the latest series of faults were but continuations of those which manifested themselves in Palæozoic times. According to Mr. J. G. Medlicott, the field data showed "that a tendency to yield in general east and west or more clearly north-east and south-west lines existed in this great area from the remote period of the Vindhyan fault".[1] The author of the memoir and map on this area was certainly not suspicious of the ideas of which I am now unburdening my mind; on the contrary, he attempted and, with apologies, failed to reconcile his facts to views then being pushed by the weight of 'authority' in Europe. This was not the last time that facts established in India were found (to use a field geologist's term) unconformably to lie on a basement of geological orthodoxy as determined by authority in Europe. It is important to notice that the series of faults referred to in the central parts of India are not mere local dislocations, but have a general trend for more than 250 miles.

A fault must be younger, naturally, than the strata which it traverses, but how much younger can seldom be determined. Intrusive rocks of known age are thus often more useful in indicating the age of the fissures through which they have been injected, and consequently the dykes which were formed at the time of the eruption of the great Deccan Trap give another clue to the direction of stresses at this critical time, that is, towards the end of the Cretaceous period, when the northerly creep had reached its maximum, just before Gondwanaland was broken up. If, now, we turn to the geological maps of the northern part of Central India, the Central Provinces, and Bengal, we find that the old Vindhyan rocks of the Narbada Valley were injected with hundreds of trap-dykes which show a general W.S.W.–E.N.E. trend, and thus parallel to the normal tension faults, which we know were formed during the periods preceding the outburst of the Deccan Trap. This general trend of faults and basic dykes is indicated on many of the published geological maps of India covering the northern part of the peninsula, including Ball's maps of the Ramgarh and Bokaro Coal-fields[2] and of the Hutar Coal-field,[3] Hughes' Rewa Gondwana basin,[4] Jones' southern coal-fields of the Satpura basin,[5] and Oldham's general map of the Son Valley.[6]

We see, then, that the development of fissures with a general east–west trend in the northern part of Gondwanaland culminated at the end of the Cretaceous period, when they extended down, probably, to the basic magma lying below the crust either in a molten state or in a state that would result in fluxion on the relief of pressure. That the molten material came to the surface in a superheated and liquid condition is shown by the way in which it has spread out in horizontal sheets over such enormous areas. Throughout this great expanse of lava there are no certain signs of volcanic centres, no conical slopes around volcanic necks; and one might travel for more than 400 miles from Poona to Nagpur over sheets of lava which are still practically horizontal. There is nothing exactly like this to be seen elsewhere to-day. The nearest approach to it is among the Hawaiian calderas, where the highly mobile basic lavas also show the characters of superfusion, glowing, according to J. D. Dana,[7] with a white heat, that is, at a temperature not less than about 1,300° C.

Mellard Reade has pointed out that the Earth's crust is under conditions of stress analogous to those of a bent beam, with, at a certain depth, a "level of

[1] Mem. Geol. Surv. Ind., vol. ii, pt. ii, p. 256, 1860.
[2] Ibid., vol. vi, pt. ii.
[3] Ibid., vol. xv.
[4] Ibid., vol. xxi, pt. iii.
[5] Ibid., vol. xxiv.
[6] Ibid., vol. xxxi, pt. i.
[7] *Characteristics of Volcanoes*, 1891, p. 200.

no strain". Above this level there should be a shell of compression, and under it a thicker shell of tension. The idea has been treated mathematically by C. Davison, G. H. Darwin, O. Fisher, and M. P. Rudski, and need not be discussed at present. Professor R. A. Daly has taken advantage of this view concerning the distribution of stresses in the crust to explain the facility for the injection of dykes and batholiths from the liquid, or potentially liquid, gabbroid magma below into the shell of tension.[1] He also shows that the injection of large bodies of basic material into the shell of tension tends on purely mechanical grounds to the formation of a depression or geosyncline. If this be so, are we justified in assuming that the heavy band following the southern margin of the Gangetic geosyncline is a 'range' of such batholiths? The idea is not entirely new; for O. Fisher made the suggestion more than twenty years ago that the abnormal gravity at Kalianpur was due to "some peculiar influence (perhaps of a volcanic neck of basalt)".[2]

Daly's suggestion, however, taken into account with the history of Gondwanaland, may explain the peculiar alignment of the heavy subterranean band, parallel to the Gangetic depression and parallel to the general trend of the peninsular tension-faults and fissures that followed the unloading of Gondwanaland and the heavy loading of the adjoining ocean bed along a band roughly parallel to the present Himalayan folds.

R. S. Woodward objected that isostasy does not seem to meet the requirements of geological continuity, for it tends rapidly towards stable equilibrium, and the crust ought therefore to reach a stage of repose early in geologic time.[3] If the process of denudation and rise, with adjoining deposition and subsidence, occurred on a solid globe, this objection might hold good. But it seems to me that the break-up of Gondwanaland and the tectonic revolutions that followed show how isostasy can defeat itself in the presence of a sub-crustal magma actually molten or ready to liquefy on local relief of pressure. It is possible that the protracted filing off of Gondwanaland brought nearer the surface what was once the local level of no strain and its accompanying shell of tension.

The conditions existing in Northern Gondwanaland before late Mesozoic times must have been similar to those in South-West Scotland before the occurrence of the Tertiary eruptions, for the crust in this region was also torn by stresses in the S.W.–N.E. direction with the formation of a remarkable series of N.W.–S.E. dykes which give the 1 in. geological maps in this region a regularly striped appearance.

There is no section of the Earth's surface which one can point to as being now subjected to exactly the same kind and magnitude of treatment as that to which Gondwanaland was exposed for long ages before the outburst of the Deccan Trap; but possibly the erosion of the Brazilian highlands and the deposition of the silt carried down by the Amazon, with its southern tributaries, and by the more eastern Araguay and Tocantins, may result in similar stresses which, if continued, will develop strains, and open the way for the subjacent magma to approach the surface or even to become extravasated, adding another to the small family of so-called fissure-eruptions.

The value of a generalization can be tested best by its reliability as a basis for prediction. Nothing shows up the shortcomings of our knowledge about the state of affairs below the superficial crust so effectually as our inability to make any useful predictions about earthquakes or volcanic eruptions. For many years to come in this department of science the only worker who will ever establish a claim to be called a prophet will be one in Cicero's sense—"he who guesses well."

[1] R. A. Daly, "Abyssal Igneous Injection as a Causal Condition and as an Effect of Mountain-building": Amer. Journ. Sci., vol. xxii, p. 205, September, 1906.

[2] *Physics of the Earth's Crust*, 2nd ed., 1889, p. 216.

[3] Address to the Section of Mathematics and Astronomy of the Amer. Assoc., 1889. Smithsonian Report, 1890, p. 196.

II.—*Papers read in Section C (Geology), Meeting of British Association, Australia, August, 1914.*

(1) THE PERMO-CARBONIFEROUS BRECCIA, A DESERT FORMATION. By H. T. FERRAR, M.A., F.G.S.[1]

DURING the meeting of the Association at Birmingham last year members of this Section had an ample opportunity for visiting the chief exposures of the so-called Permian breccia of the midland counties of England. This deposit may be briefly described as a mass of sandstones and marls with occasional sheets of angular breccia, the latter consisting in a large measure of volcanic rocks, grits, slates, and limestones which can be identified with rocks on the borders of Wales. The organic remains which have been recorded are few, but such as occur are indicative chiefly of terrestrial surfaces.

The origin of the breccia has given rise to many speculations, amongst which may be mentioned—

1. Murchison (1839) regarded it as a volcanic or trappoid breccia marking the position of underground masses of volcanic rocks hidden under a cover of their own fragments.

2. Ramsay (1855) ascribed its origin to the existence of glacial conditions in Permian times.

3. Geikie (1892) says with regard to Scotland that the breccia has evidently accumulated in small lakes or narrow fiords during periods of great and rapid denudation following uplift of the Upper Carboniferous rocks.

4. Bonney (1902) concludes that breccias are usually indicative of continental conditions, but that glaciers are necessary for the transport of the larger boulders.

5. Lapworth (1912) holds that they are the memorials of local Alpine conditions.

In Egypt a chain of fold-mountains forms the watershed between the Nile and the Red Sea, and the mountains are intersected and drained by steep-sided gorges or wadis. The climate is arid with occasional heavy thunderstorms causing temporary torrents, which sweep forward all rock-material loosened during the prevailing dry climate. The wadi beds receive continuously a fresh supply of angular debris shed from the adjacent bare hillsides, and any fragments which may have become rounded or subangular are often shattered before the next flood sweeps them forward another stage on their journey towards a more permanent resting-place, namely, the alluvial plain at the wadi-mouth. Blocks slipping down the bare hillsides become scratched or they may be scratched by mutual impact during a sudden rush of flood-water. Great blocks are often carried fifty or one hundred miles down the wadi channels, and the agency of ice need not be invoked to explain their transport.

The valley fill of most wadis in the Eastern Desert of Egypt is an unconsolidated breccia so similar to the breccia exposed on Ley Hill, near Birmingham, that there is little room for doubt that the two originated under similar climatic conditions.

[1] By permission of the Director-General, Egyptian Survey Department.

(2) Climates and Physical Conditions of the Early Pre-Cambrian. By Professor A. P. Coleman, F.R.S., Toronto.

Our knowledge of the later Pre-Cambrian permits us to speak of desert conditions in the Keweenawan or Torridonian and of an ice age followed by a cool climate in the Huronian, but little evidence has been given as to earlier climates. Recent work in Canada shows that the Sudbury Series, of Pre-Laurentian age and very much older than the Huronian, includes all types of sediments, often well enough preserved to show cross-bedding, ripple-marks, and annual layers indicating the change of seasons. They must have been formed near the margin of a continent where granites weathered under a cool and moist climate. They seem to be delta materials deposited by great rivers.

The highly metamorphosed sediments of the still older Grenville and Keewatin Series (Lewisian?) have lost their original structures, but the gneisses, quartzites, and marbles must have been clay, sand, and limestone in the beginning, and the graphite may have originated in plants. Land surfaces must have been attacked by water and air to produce these materials, and there is no evidence that the climate was hot. These are the earliest known formations, so that air and water worked in the usual way at the beginning of recorded geological time.

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(3) The Tertiary Brown Coal-beds of Victoria. By H. Herman, B.C.E., M.M.E., F.G.S., Director of the Geological Survey of Victoria.

The brown coal-beds of Victoria are probably the thickest yet recorded in the world. The more extensive areas are the La Trobe Valley, Alberton, Altona, and Lal Lal. Minor beds are widely distributed.

The geological age has not yet been definitely fixed, except at Altona, where a brown coal-seam 140 feet thick underlies marine Oligocene beds. Flows of basalt overlie the brown coal in places, and underlie it in others. The range in age is probably from Oligocene upwards. Seams outcrop at Narracan, Thorpdale, Dean's March, Morwell, and Boolarra.

Where below the surface, the seams are prospected by boring. In many bores coal of several hundred feet in thickness is shown; one bore had an aggregate thickness of 781 feet of coal in a depth of 1,010 feet. The overburden is from a few feet to 500 feet deep.

In the Alberton area of about 300 square miles and the La Trobe Valley area of 700 square miles there is probably 30,000,000,000 tons of coal. The approximate area at Altona is 200 square miles, with a probable average thickness of 50 feet of coal. At Lal Lal the coal covers 3 square miles with an average thickness of 80 feet.

The geological and geographical distribution of the various brown coal-seams is still being ascertained by boring; the bores are being systematically tested for calorific value, gas production, and by-products. A typical analysis of the brown coal, as freshly mined, is—

	Per cent.
H_2O	53·00
V.H.C.	24·50
F.C.	21·50
Ash	1·00
	100·00
Sulphur	0·7 per cent.
Nitrogen	0·3 per cent.
Calorific value	5500–6000 B.T.U.
Evaporation value	4 lb. water.
Gas per ton	6,500 cubic feet.
Ammonium sulphate per ton (theoretical)	32 lb.

Experimental work has also proved that under proper conditions a firm hard briquette can be produced without the aid of an agglutinant binder. It is suitable also for use in the gas producer, the improvements in which of recent years bid fair to give brown coal an important place in the power-fuels of the world at no distant date.

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(4) THE SEDIMENTARY ROCKS OF SOUTH VICTORIA LAND. By F. DEBENHAM, B.A., B.Sc., Geologist to Captain Scott's Last Expedition, 1910–13.

THE topography of the area was first described in brief, showing how the comparatively meagre knowledge of the geology of such a vast region is due largely to its plateau structure, which presents merely an edge of the continent, the interior being completely covered by a thick ice-cap. The systems at present known to occur were then described in order of their age.

1. The Foundation Rocks, a vast complex of gneisses, schists, and crystalline limestones, largely of sedimentary origin, with their axes of folding in a meridional direction. They must at present be referred to Pre-Cambrian age, though a less altered series of slates and quartzites in the Cape Adare region may possibly be younger.

2. The Cambrian of the Beardmore Glacier. The outcrop of this series has not yet been visited, the evidence for its occurrence being derived from moraine blocks. Its probable disposition was sketched, and a possible connexion between the Archæocyathinæ found in these blocks and those found in the Weddell Sea was traced.

3. The Upper Devonian shales of Granite Harbour. This thin bed of shales was formerly supposed to be a part of the Beacon Sandstone Series, with which it is quite conformable, but evidence was brought forward to prove that it is of earlier date, the most important being the occurrence of numerous Devonian fish scales.

4. The Permo-Carboniferous Sandstones. The already well-known Beacon Sandstone was proved to be of this age from the fossils brought back by the last expedition. The series was thoroughly described from three type areas, and its probable limits indicated. An attempt to correlate it with other large Permo-Carboniferous regions in the world was made, having special regard to the Australian examples. The great variations in lithological character in different parts of the series was described, and reasons for them suggested from the stratigraphical relationships, with a sketch of the probable climatic

conditions at the time of deposition drawn chiefly from the internal evidence of the sandstones. The coal-beds associated with the series were described in detail.

5. Recent. A brief description of the only other sedimentary deposits yet found was given, they consisting chiefly of local beds of volcanic tuffs and some moraine deposits.

The paper concluded with a brief sketch of the history of South Victoria Land as compared with that of the South American Quadrant as recorded by their respective sedimentary deposits.

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(5) Victoria Graptolites. By T. S. Hall, M.A., D.Sc., Lecturer in Biology in the University of Melbourne.

The Silurian and Ordovician graptolite-bearing rocks of Victoria occupy about 20,000 square miles, and over a hundred species have been recorded.

Very little is known of the Silurian. The Ordovician is divided into Upper and Lower, but probably represents a continuous series. The Upper is characterized by the presence of Dicranograptidæ. No zonal work has been done in the field, though collections yielding about fifty recorded species have been made.

Four divisions are recognized in the Lower Ordovician, namely, Darriwillian, Castlemainian, Bendigonian, and Lancefieldian, at the base. There are several subdivisions of these formations. The characters were briefly indicated in the Geological Magazine by the author in 1899. Subsequent work by T. S. Hart, F.G.S., at Daylesford, has confirmed the sequence established. Large collections made by the Survey at many localities have somewhat extended our knowledge of the fauna and its distribution, but without adding any features of great importance.

The Upper Ordovician ranges north from Eastern Victoria for 300 miles into New South Wales. In New Zealand Lancefieldian occurs at Preservation Inlet, and two Castlemaine zones occur as well. It is probable that the Victorian sequence, and not the British, as stated, will be found.

Broadly, the sequence of Australian Graptolites agrees with the European, but in details is closer to that of New York, as Ruedemann has pointed out. The important differences in the range of *Didymograptus bifidus*, *D. caduceus*, *D. nicholsoni*, *Loganograptus*, *Clonograptus rigidus*, and some other genera and species negative the idea that graptolite zones are world-wide, and as no one believes that all genera and species originated in one locality and radiated thence this is what we should expect.

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(6) On the Term Permo-Carboniferous and on the Correlation of that System. By W. S. Dun and T. W. Edgeworth David.

The term Permo-Carboniferous was originally applied to certain formations in Queensland which on stratigraphical evidence were at the time considered to belong to one and the same general system. At the time it was considered that a series of strata at

Gympie, which contained an assemblage of fossils of distinct Permian affinities, were stratigraphically below another set of strata known as the Star Beds. The latter contain among other fossils *Phillipsia*, *Lepidodendron Australe*, and *Aneimites*, all typical Carboniferous fossils in Australia, and the first mostly of Devonian age. Accordingly these formations were grouped together under the term Permo-Carboniferous, and the name has subsequently been widely used. It has now been proved that, so far as Queensland is concerned, the name has been given in error. The Gympie Beds are stratigraphically above the Star Beds, not below as was originally supposed. Nowhere in Australia or Tasmania has a single trilobite or *Lepidodendron* ever been found in our Carboniferous rocks proper. In the absence of a zoning of these Carboniferous rocks it is impossible to say what exactly are its equivalents in other parts of the world. If it is wholly Lower Carboniferous, as some suppose, there may be some justification for the retention of the term Permo-Carboniferous, but if its fauna and flora ascend to Upper Carboniferous, then it is suggested that there is much to be said in favour of using the term Permian instead. In Russia *Schizodus* occurs in numbers beneath the whole, not only of the *Glossopteris* beds, but of the *Gangamopteris* beds also of the Dwina system. In South America the Lower Rocks of the Santa Catharina system appear to be more Permian than anything else, and the occurrence of the strong swimming reptile *Mesosaurus* both in the Permo-Carboniferous rocks of South America and of South Africa suggests that the South African Permo-Carboniferous rocks also may be chiefly Permian.

In the correlation of the Australian Permo-Carboniferous formations, special emphasis is laid on the Indian facies of the West Australian Permo-Carboniferous fauna.

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(7) The Evolution of Victoria during the Kainozoic Period. By D. J. Mahony, M.Sc., F.G.S., Geological Survey of Victoria.

The Kainozoic period in Victoria is characterized by great earth movements accompanied by volcanic action; the present topography is a consequent development.

The central highland area (Palæozoic rocks) extends from the eastern boundary of the state westwards to the Grampians; to the north and south it is bounded by low-lying plains (Kainozoic strata), which gradually broaden towards the west until they merge into one another. To the south Wilson's Promontory (granite), South Gippsland (Mesozoic), and the Cape Otway district (Mesozoic) rise above the plains. The highland area is essentially a dissected peneplain sinking from some 5,000 feet above sea-level in Gippsland to 900 feet at its western extremity; the only Kainozoic rocks upon it are river-gravels, lake-deposits, and volcanics.

The plains (500 feet) are areas of Kainozoic sedimentation with some interbedded and overlying volcanic rocks; the sedimentary series consists of lacustrine or estuarine beds, followed by marine clays (Oligocene), foraminiferal limestones (Miocene), and sandstones (Pliocene). These beds rest upon Palæozoic or Mesozoic rocks.

On the surface of the ancient peneplain, 5,000 feet above sea-level, (?) Miocene plant-remains and river-gravels are preserved beneath basalt at Dargo High Plains. This indicates a long pre-Miocene period of quiescence followed by a great uplift. This area has not been submerged during the Kainozoic.

The nature of the Kainozoic Series indicates that, outside the highland area, a gradual subsidence of considerable magnitude (Oligocene and Miocene), accompanied by volcanic outbreaks (Miocene), was followed by re-elevation to a maximum of about 900 feet above sea-level (Pliocene or post-Pliocene). There is evidence to show that the movements were not uniform in direction, though the net result was depression or elevation. Bass Strait is a recently sunken area in which equilibrium has not yet been established.

The nearly horizontal position of the Kainozoic rocks indicates that the movements were vertical; and there are, moreover, examples of Kainozoic faults in which the differential movement amounts to 900 feet.

The volcanic rocks are basaltic except for sporadic occurrences of alkali rocks in Eastern, Central, and Western Victoria.

The Older Basalts are most abundant to the east of Melbourne. Some remnants occur on the ancient peneplain 3,000 feet above the present streams, but the most extensive areas are at lower levels in South Gippsland. At Flinders the Older Basalt underlies marine Miocene, and has been proved by boring to be over 1,300 feet thick, and to extend from sea-level to that depth. In some instances the age can be conclusively proved, but in others the evidence is poor. These basalts are associated with the first great period of earth movements.

The Newer Basalts are most extensively developed in the western district, where their northern boundary is not far from the 500 ft. contour; here they overlie marine Kainozoics. Large areas are also found on the plateau west of Kilmore and along its northern flanks. The Newer Basalts are never covered by marine deposits, except recent accumulations near the coast, their surface is little denuded, and many of the cones of loose scoria are almost perfect. It appears that the Newer Basalts mark the close of the last great movement which elevated the marine Kainozoics.

In New South Wales and South Australia earth movements on a grand scale took place during the Kainozoic period, yet volcanic action was comparatively insignificant.

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(8) On the Tertiary Alkali Rocks of Victoria. By Ernest W. Skeats, D.Sc., A.R.C.S., F.G.S., Professor of Geology and Mineralogy, University of Melbourne.

FROM Mount Leinster in Benambra, Frenchman's Hill near Omeo, and Noyang in Dargo, three areas in Eastern Victoria, the late Dr. Howitt (1) described igneous rocks which belong to the alkali series. They were all regarded by Howitt as of Palæozoic age. The age of the rocks of Noyang, which consist mainly of intrusions and lava-flows of quartz-ceratophyre, has not been closely investigated and may be Palæozoic. Recent work (2), however, has shown, especially in the case of the Omeo rocks, that they are probably of mid- or even of late Tertiary age. The alkali rocks of Frenchman's Hill, described by Howitt as intrusive orthophyres, consist really in the main of lava-flows of anorthoclase trachyte which has a very scoriaceous margin to the flows. There is a central plug of a coarser quartz-bearing rock allied to solvsbergite and a more or less radial system of dykes which are principally trachytic in character. Some, however, contain quartz, one at least is a bostonite, and six or seven prove to be dykes of nepheline phonolite. The district is one which has been affected by a succession of elevatory movements of the plateau type since the mid-Tertiary period, and, according to Griffith Taylor (3), a more or less meridional Senkungsfeld runs through the Omeo District a few miles east of Frenchman's Hill. The rocks of Mount Leinster in Benambra consist principally of solvsbergites, bostonites, and pyroclastic rocks of alkali trachyte. Petrologically and chemically many of the rocks of Mount Leinster and of Frenchman's Hill closely resemble some of the alkali rocks of Mount Macedon, and, like them, are probably of mid-Tertiary age. The district has been elevated at intervals during the Tertiary period, but physiographically has not been closely studied.

About 14 miles north-east from Mansfield in North-Central Victoria and about 3 miles from Tolmie, in the Tolmie Highlands, there occurs a volcanic hill, known locally as Gallows Hill, which has recently been shown to consist of a volcanic centre of probably late Tertiary age and to consist of lava-flows of nepheline phonolite. From a locality near Barwite, east of Mansfield, another nepheline phonolite has been found, but its field relations are at present uncertain and no account of either of these rocks has yet been published. Fenner (4) has recently shown that block elevation and depression have affected the Mansfield area in recent geological times, and that Gallows Hill lies near one of the fault scarps.

The best-known area of alkali rocks in Victoria is the Mount Macedon District, about 40 miles north-west of Melbourne (5). The series is of mid-Tertiary to late Tertiary age, and the rock sequence from below upwards, while not always demonstrable, appears to be as follows: anorthoclase trachyte, solvsbergite, anorthoclase basalt, macedonite, woodendite, anorthoclase-olivine trachyte, olivine-anorthoclase trachyte, limburgite. Immediately succeeding these alkali rocks come lava-flows of normal basalt and of andesitic basalt. The new types macedonite and woodendite contain over 1 per cent of P_2O_5, and are related to the orthoclase basalts and to the mugearites.

While this part of Victoria shows evidence, by the existence of more than one elevated peneplain, of successive movements of the plateau type, no definite evidence of faulting or differential movement has been recognized in the district. In the western district of Victoria more or less extensive lava-flows of anorthoclase trachyte occur near Coleraine, Carapook, etc. (6). Generally the trachytes appear to be older than the newer basalts, but near Coleraine a dyke of trachyte penetrates a small hill composed of a basic rock resembling olivine basalt, while at the Hummocks north of Casterton another trachyte dyke similarly penetrates a vent or small flow of olivine basalt. Among the ejected blocks from the earlier members of the Pleistocene newer basalts of Lake Bullenmerri, near Camperdown, are some consisting of essexite and containing analcite. In the western district of Victoria clear evidence of comparatively recent elevatory movements is noticeable. No definite faults have yet been proved, however, and the normal basalts are much more widely spread than the alkali rocks. In view of Harker's generalization as to the close correspondence between the occurrence of alkali rocks and elevatory movements of the plateau type, generally accompanied by faulting, the above reference to earth movements is pertinent. Practically no folding movements are known among the Tertiary rocks of Victoria, while plateau movements, generally of elevation, sometimes of depression and accompanied by faulting, are widespread. Near Omeo and Mansfield, where faulting has been demonstrated or inferred, the highly alkaline types of nepheline phonolite are developed, but the widespread plateau movements in Victoria are more specially associated with the occurrence of the normal basalts. The alkali trachytes and allied rocks are intercalated between an older and a newer basalt series, are developed only sporadically at certain centres, and, as at Macedon, are closely associated in the field with the newer basalts as rocks of slightly greater antiquity but belonging to the same volcanic period.

References to Literature.

1. Howitt, A. W. Rep. Min. Dept. Vict., September, 1890; Rep. Min. Dept. Vict., March, 1890; Trans. R. Soc. Vict., vol. xx, 1884.
2. Skeats, E. W. Aust. Ass. for Adv. of Science, Brisbane, 1909, Presidential Address to Section C; Aust. Ass. for Adv. of Science, Sydney, 1911.
3. Griffith Taylor, T. Com. Bureau of Meteorology, Bulletin No. 8, 1911.
4. Fenner, C. Proc. Roy. Soc. Vict., n.s., vol. xxv, 1913.
5. Gregory, J. W. Proc. Roy. Soc. Vict., n.s., vol. xxv, 1901.
Skeats, E. W., and Summers, H. S. Geol. Surv. Vict., Bulletin No. 24, 1912.
6. Summers, H. S. Aust. Ass. for Adv. of Science, Sydney, 1911.
66. Dennant, J. Aust. Ass. for Adv. of Science, Adelaide, 1893.
66. Hogg, E. Proc. Roy. Soc. Vict., n.s., vol. xii, 1899.

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(9) On the Origin and Relationship of the Victorian Kainozoic Alkali Rocks. By H. S. Summers, D.Sc.

Alkali rocks of Kainozoic age occur in Victoria in the Macedon District, near Coleraine and Carapook in the Western District, and in the neighbourhood of Omeo and Mansfield in North-Eastern Victoria. Ejected blocks from the volcanoes near Camperdown have been described as essexite, and a similar type, also probably ejected, has been found near Kyneton. With the exception of the occurrences of Omeo and Mansfield all these alkali rocks are closely associated with the Upper Kainozoic calcic basalts, and the field relations are such that there is little doubt that the alkali rocks and the basalts are genetically related.

Numerous analyses (mainly unpublished) have been made of Victorian basalts, and these show that they are fairly normal in composition, and consequently should belong to Harker's Calcic or Pacific Branch of Igneous rocks, whereas the solvsbergites, trachytes, etc., of Macedon, the phonolites of Omeo and Mansfield, the essexites (?) of Camperdown and Kyneton, and the trachytes and anorthoclase basalts of the Coleraine area must be placed in the Alkali or Atlantic Branch. It follows, then, that the evidence of the Victorian Kainozoic rocks does not support Harker's generalization on Petrographic Regions.

A number of first-class analyses have been made of the principal types of the Macedon Series, and variation diagrams based on these analyses have been drawn (see Bulletin of the Geological Survey of Victoria, No. 24, 1912, and Proceedings of the Royal Society of Victoria, N.S., vol. xxvi, pt. ii, 1914). It was found that by re-calculating the analyses to 100 per cent with the water omitted and the ferric oxide reduced to ferrous, the curves obtained were better than those plotted from the original analyses. Certain of the analyses did not conform to the curves, and at first these were regarded as representing hybrid types, but additional work showed that they represented complementary types and resulted from the splitting up of a magma instead of the mixing of magmas. A few analyses have been made of the alkali rocks from other Victorian areas, but a sufficient number have not been made to show the relationship of the various types to one another.

The conclusions are that the Kainozoic alkali rocks of Victoria are derived from the calcic basalts by differentiation, giving rise to several lesser magma reservoirs. In the case of the Macedon magma further differentiation took place, and a series of lavas were extruded which in general showed a serial relationship to one another, but a certain number were complementary to one another.

REVIEWS.

I.—Igneous Rocks and their Origin. By R. A. Daly, Sturgis-Hooper Professor of Geology, Harvard University. New York and London, 1914.

EVERY field-student of igneous intrusions must at some period of his career have been confronted by the following problem: before the intrusion occurred, what occupied the space now filled with igneous rock, and what has become of that material? Up to the present time this problem has scarcely been considered by British petrographers, at any rate in print, whatever may have been their private speculations on the subject. This is the most important question that the author of this book sets out to answer; if, after reading it, we are not perhaps prepared to accept all his conclusions in full in exactly the sense intended by the author, it is at any rate clear that he has provided abundant food for thought among petrologists.

Professor Daly has long been known as an advocate of *stoping* as an important mechanism in rock-intrusion. Now, stoping is merely another name for assimilation, since it implies the fusion and incorporation of blocks of the country rock sinking in the invading magma. Many of the older petrologists believed that igneous intrusions, such as granite, were formed by the simple fusion in place and recrystallization of 'country rock' normally sediments. Chemical analysis soon showed this hypothesis to be untenable in such a simple form, but Professor Daly's ground idea is really a modification of this; he postulates an original acid granitic shell, underlain by a basic basaltic shell; by mixtures of these, and by mixtures of basaltic magma and sediments (syntectics) assisted by differentiation, he derives all possible igneous rock-types, in many cases with much plausibility. It is important to note that this theory does not propose to explain fully the igneous history of the earliest pre-Cambrian times; it only professes to deal with the phenomena of later pre-Cambrian (post-Keewatin) and post-Cambrian times. The earlier events seem to have consisted largely in the differentiation by gravity of the fundamental granitic and basaltic shells. The later events are explained in large part as due to the penetration of wedges of the underlying basaltic magma into the granitic shell and into the sediments that subsequently came to overlie it.

One of the chief lessons to be learnt from a careful reading of this book is the unimportance, in fact even the danger, of an elaborate nomenclature. The names applied to rock varieties are legion; some 700 different rocks have been defined and indexed; a very large proportion of these are varieties of the so-called alkaline rocks. Hence we obtain a distorted and unnatural idea of the importance of this group. When, however, the quantitative method is applied, as is done by Professor Daly, things soon begin to appear in more accurate proportion. It is estimated by the author that in North America the alkaline rocks amount to less than one-tenth of 1 per cent of all the igneous rocks, perhaps even less than this, and in Europe certainly to less than 1 per cent. Here, then, the appalling list of rock-species of alkaline type, including pulaskite, kakortokite, naujaite, lujaurite, ouachitite, bekinkinite, and many other efforts of a diseased petrological imagination, sink into their true insignificance, and the great fundamental fact emerges that the alkaline rocks as a whole are only incidental products of a planet whose eruptions and intrusions have been overwhelmingly of sub-alkaline quality. Furthermore, from this quantitative treatment, it is clear that basic sub-alkaline rock-types predominate in the extrusive phase of igneous action, acid sub-alkaline types in the intrusive phase, or, in other words, abundant evidence is brought forward to show that the normal rock-types of the world are granite and basalt. Apart from theory, this is a fact of observation resting on statistics accessible to all, and geologists are much indebted to Professor Daly for having laid emphasis on such an important, but for long unrecognized, truth.

In the light of these facts, the great and commonly accepted division of rock-species into Atlantic and Pacific types loses most of its force, at any rate in so far as concerns their connexion with different types of earth movement, or with actual geographical distribution. The same applies with perhaps even more cogency to the recent attempts to introduce a third, spilitic, series, which appears to differ in no fundamental character from either of the other two. The spilites appear to be simply normal basalts in which the soda molecule has been concentrated by some kind of pneumatolysis or differentiation, which in this respect are really much the same phenomenon under different names.

Perhaps the least satisfactory part of the whole treatment is the explanation that is offered for the highly alkaline rock-types, nepheline syenites, phonolites, leucite rocks, and so forth. For this is given what appears at first sight the paradoxical explanation that they are due to the assimilation by sub-alkaline magmas of limestone or dolomite. These materials are supposed to act as powerful fluxes, greatly facilitating the differentiation of the magma, and leading to concentration of its salic constituents in one portion and its calcic and femic molecules in the other portion. Evidence is brought forward to show the extremely common association of such exaggeratedly alkaline rock-types with limestones in rocks of all ages. Here and elsewhere great importance is attached to the idea of the so-called 'two-phase convection' as an agent of differentiation. Space will not here permit of a discussion of the validity of this conception, which is obviously of very great importance.

It only remains to express the thanks of the petrological world to Professor Daly for bringing forward such a notable contribution to scientific petrology, which is bound to have a far-reaching effect, and by its frank and fearless discussion of many accepted dogmas must eventually help us in our slow progress towards the truth.

R. H. R.

II.—The Water Supply of Nottinghamshire from Underground Sources. (Memoirs of the Geological Survey, England and Wales.) By G. W. Lamplugh, F.R.S., and B. Smith, M.A.; with a chapter on the rainfall by H. R. Mill, D.Sc., LL.D. pp. 174, with 2 plates and 2 text-figures. Price 5*s*.

THIS memoir forms a notable addition to the series on the Water Supply of English Counties. The underground water is of great economic importance, since almost the whole of the supply is now derived directly from this source, the surface-water being in nearly every instance too much contaminated for use. The rocks of the county are fortunately peculiarly well adapted for the absorption and storage of the rainfall, and the most extensive of the water-bearing formations is conveniently situated for the supply of the industrial centres.

In ch. i an outline is given of the arrangement and character of the geological formations. The general dip of the strata is to the east in the northern part of the county, swinging round to the south-east in the southern part, and it is almost everywhere at a low angle, rarely so much as 5 degrees. A geological map on the scale of 4 miles to 1 inch forms plate i, and on this lines are drawn to indicate the contours of the top of the Bunter beneath the overlying formations, at depths below Ordnance Datum, at intervals of 200 feet. The outcrop of the Bunter Pebble Beds and Lower Mottled Sandstone occupies an area of 240 square miles in the county, and it is from these beds that most of the water is derived. A sketch-map of part of North Nottinghamshire shows the underground water-level in the Bunter in 1909; the contours of the water-table are drawn at 5 ft. intervals, and the height above O.D. is given in feet. It is estimated that the yield, from the Bunter, of public wells is about fourteen million gallons a day, and of private wells about seven or eight million gallons.

In ch. ii it is noted that the average rainfall responds to the configuration of the county in a striking manner. The lowest rainfall, less than 25 inches, is confined to the low ground of the Trent Valley, and the isohyetal line of 25 inches coincides roughly with the contour-line of 150 feet of elevation in the south and that of 100 feet in the north. The isohyetal of 30 inches keeps near the contour of 500 feet in the west of the county. The local description of the water supply is dealt with under five districts, which are partly topographical and partly geological, and references are here given to the fuller geological and other details contained in the subsequent chapters, in which the records of well-sections and a large number of analyses are brought together.

III.—Classification des Lamellibranches. Par H. Douvillé. Bulletin Société Géologique de France, ser. iv, tom. xii, pp. 419–67, figs.

THIS paper, owing to its publication in a journal not open to all, runs the risk of not receiving the attention it deserves.

After summarizing the various systems of classification that have been proposed for the Pelecypoda, beginning with that advanced by Neumayr in 1883, the author discusses the nature and development of the shell and roughly divides the group into those that live free, those that are attached, and the crypt dwellers or burrowers.

Three types of characters attach to the Pelecypoda.

1. *Evolutionary characters.* Thus in the ancient forms the shells were nacreous, but became porcelainous in their descendants during the course of their evolution.

2. *Adaptive characters* due to environmental conditions and giving rise to like forms of test in animals of distinct stocks, e.g. *Mytilus* and *Dreissensia*, *Ostrea* and *Chondrodonta*, *Solen* and *Ensis*, etc.

3. *Static characters*, or those which change least. The hinge is the best example of this type and is consequently the one mainly relied on by the author for the purposes of classification.

An extremely interesting and well-illustrated section follows, giving the different forms of hinge and their evolution, whilst the paper concludes with a tabular statement of the phylogenetic grouping proposed.

This shows the primitive nacreous forms divided into three groups; Taxodonta, comprising the free forms; Dysodonta, or fixed forms; and Desmodonta, or crypt dwellers and burrowers, including such forms as the Corbulidæ, etc., that have secondarily become free but retain the hinge characters of the group.

In the Taxodonta, through *Ctenodonta* and *Palæonilo* arise the Nuculidæ and kindred forms; whilst through *Actinodonta* spring on the one hand the Anthracosiidæ and Unionidæ, and on the other *Modiomorpha* and a group to which the name Preheterodonta is applied. This last in turn gives off two branches, the one comprising the Myophoridæ and Trigoniidæ, the other leading through *Megalodon* to the Heterodonta.

The Dysodonta have also two branches: firstly, *Palæarca* and the Arcidæ; and secondly, Pterineidæ, giving off the Mytilidæ (with *Conocardium* and *Lunulicardium*) and the Aviculidæ (i.e. Pteriidæ), Pectinidæ, Limidæ, and Ostreidæ.

Finally, the Desmodonta, beginning with the Solenopsidæ, pass up through the Grammysiidæ to the forms usually included under Myacea, Adesmacea, and Anatinacea.

To what extent M. Douvillé's scheme will stand the test of close investigation remains to be seen. Probably his interpretation of the hinge characters may in certain cases have to be revised, but the broad outlines seem well conceived, and his paper merits the careful attention of all interested in the Mollusca.

B. B. W.

IV.—Catalogue des Invertébrés fossiles de l'Égypte représentés dans les Collections du Musée de Géologie au Caire. Par R. Fourtau. Terrains Crétacés. 1re partie : Échinodermes. 4to; pp. i–vii, 1–109, pls. i–viii. Cairo: Geological Survey of Egypt, Palæontological Series, No. 2.

If the present rate of output is maintained the collections of the Geological Museum at Cairo will soon rank among the most completely and thoroughly catalogued material extant. The first part of the Catalogue, dealing with the Eocene Echinoids, was reviewed recently in these pages, and now the second part is published. The style and production of this volume leave little field for criticism. It is perhaps a little confusing that, whereas the first part had a title-page printed entirely in French, the present part has all but the actual name of the work in English.

The number of misprints seems to be remarkably small, a gratifying feature in view of their serious frequency in the first part. The plates are, if anything, clearer both in drawing and execution than were the previous series, and their concentration at the end of the volume renders them easier of access than did their insertion in various parts of the text.

Although Asteroids and Crinoids are mentioned in the work, there is little fresh material recorded. A new genus, *Spenceria*, is proposed for *Metopaster teilhardi*, the name being given in recognition of the work of Mr. W. K. Spencer on Cretaceous Asteroids. The bulk of the volume is occupied by a descriptive catalogue of no fewer than 122 species and varieties of Echinoids, of which but a small proportion are new. In common with many other workers on

Echinoids, M. Fourtau seems to be appalled by the great number of species that are accumulating under certain generic names, and he attempts to mitigate the evil by degrading certain 'species' to the ranks of varieties, races, and mutations. This method seems fully justifiable, so long as it is carried out uniformly. Unfortunately M. Fourtau does not give any indication of the precise significance (for him) of the three subspecific terms employed. It is possible, from a study of the actual cases, to glean some information on this score, but a simple statement, or a definition, would have rendered the process of 'despecification' more intelligible. It seems that, for M. Fourtau, a 'variety' is a form that differs from the type in some slight respects, but may be discovered over wide areas, including the type locality; while a 'race' is a local variant confined to some region other than the type locality. There is not sufficient evidence to speculate on the propriety or otherwise of the use of the much harassed term 'mutation'.

An interesting feature of the variation of some of the species of *Hemiaster* is the parallelism of the lines along which they tend to vary. Thus the four different forms of *H. cubicus* are matched closely by a corresponding four in *H. heberti*. Here surely is further evidence in support of the principle of the fixity of the trend of evolution among separate but homogenetic races—a principle that has been urged by the present writer in several recent papers.

There is little of outstanding interest in the new species described in the Catalogue, if we except the *Schizaster*. A fresh bridge has thus been thrown across the Cretaceo-Eocene gulf by the occurrence of so essentially Tertiary a genus in the Maestrichtien.

One further aspect of the work demands comment. In the Introduction M. Fourtau refers to a suggestion (made in the review of the previous volume) that he should not confine his efforts to mere description, but give to the world the ideas that his acquaintance with these numerous Echinoids has surely engendered. He contends that a catalogue is not adapted for the expression of personal opinions on the material dealt with. Granted, but there are other channels of publication. M. Fourtau also seems to infer that, until all the material is known and systematized, conjecture and theory are alike premature. Surely here he resigns himself to perpetual silence; there will be fresh material appearing throughout his lifetime, long as we hope that period may be. Indeed, such a suggestion, whether it is prompted by tenderness of conscience or feebleness of courage, is in every way to be condemned. The average human mind is not a mere machine for the production and arrangement of species and genera after the manner of a cash-register. These must be strung together into a chain of evolution, even if some of the links have to be imagined. The spurious links may be faulty, and require frequent renewal or replacement, but, when some of the links are in their right order, the rest can in time be adjusted. To change the simile, M. Fourtau spreads before us many of the wheels, screws, and springs of an intricate machine, all loose and in disorder. He, more than any man, is capable of judging as to which cogs fit and which portions are lost. Every year adds to the pile of fragments, and they are getting bewildering in their profusion. Cannot a *few* of them be fitted together *now* ?—thus only can we hope to understand the meaning of the rest.

H. L. H.

V.—The San Franciscan Volcanic Field, Arizona. By Henry Hollister Robinson. United States Geological Survey, Professional Paper 76. pp. 213, with 14 plates and 36 text-figures. 1913.

THE San Franciscan volcanic field, which takes its name from San Francisco Mountain, the largest volcano of the group, covers about 3,000 square miles in the north-central part of Arizona. The State is divided into the Plateau and Basin Range provinces, and the latter is subdivided into the Mountain and Plains districts. The topography of these divisions is discussed and an account is given of the particular features of the volcanic field, which is situated in the Plateau province.

The description of the drainage of the area is of much interest, especially the examples of the changes caused by the damming of watercourses by lava-flows. A chapter is devoted to the sedimentary rocks, the structure, and the glaciation and alluvial deposits of San Francisco Mountain. The oldest rocks of the region are of Mississippian (Lower Carboniferous) and Pennsylvanian (Upper Carboniferous) age, and furnish a record of continuous marine sedimentation. The Mœncopie formation, which is probably of Permian age, rests on a somewhat eroded surface of the older rocks, and consists of fluviatile or shallow-water deposits. Then follow Triassic sandstones, shales, and marls which show evidence of continental deposition. No traces are left of the Jurassic, Cretaceous, and possibly Eocene strata which once covered the area.

The phenomena of the volcanic region are dealt with at length. Three general periods of volcanic activity, separated by intervals of quiescence are recognized. The phenomena of the first period were of a simple nature, and consisted of widespread eruptions of basalt from small cones. During the second period various lavas, ranging from andesites to rhyolites, were erupted and built up a few large cones. This period was further marked by laccolitic and semi-laccolitic intrusions contemporaneous with the volcanic extrusions. The third period closely resembled the first in that it witnessed the eruption of a single lava, again a basalt, but it was characterized by the formation of a larger number of cones and a less widespread distribution of the lava. Each period receives separate treatment, and the details of the character, extent, and conditions of extrusion of the erupted material are carefully worked out and illustrated by maps and photographs of the principal cones.

There is an interesting chapter on the history of the volcanic field and adjacent country. This is followed by chapters on the petrography and petrology, in which the detailed description and classification of the igneous rocks and the differentiation and composition of the magma are dealt with. Analyses are given of all the important rock types.

OBITUARY.

H. J. JOHNSTON-LAVIS, M.D., M.R.C.S., F.G.S.,

VITTEL, VOSGES, FRANCE.

As we go to press we learn with great regret that Dr. H. J. Johnston-Lavis has been killed in a motor accident at Bourges (Department of Cher), France. He appears to have been on his way from Paris taking his invalid wife to their daughter at Biarritz. Madame Lavis escaped. We hope to give an obituary notice in a later number of the Magazine.

MISCELLANEOUS.

THE TYPE OF *PLIOLOPHUS VULPICEPS*, OWEN.—In 1858 Richard Owen described the head and other portions of a skeleton of a small mammal from the London Clay of Harwich under the name of *Pliolophus vulpiceps*. He had made a section through the lower jaw, and that section was, so far as we knew, the only fragment of the original skull which survived. It is in the British Museum. The specimen belonged to the Rev. R. Bull, vicar of Harwich, and was supposed to have perished. Such was a tradition with the late Mr. William Davies, and Woodward and Sherborn failed to trace it when writing their *British Fossil Mammalia*. But only two weeks ago a message was received from the widow of Mr. Bull saying that the specimen was not only preserved but that she wished to deposit it in the British Museum in accordance with her late husband's desire. The little skull and limb bones are as perfect as when Owen left them, and still bear his labels. The section of the jaw now in the Museum fits on exactly to the cut in the skull.

The recovery of this long-lost type is of extraordinary interest, for it is the earliest known horse, and its proper position is ascertained from work done since its time in America and elsewhere. It is greatly to be hoped that the specimen may be redescribed in the light of modern knowledge, and the thanks of all palæontologists are due to Mrs. Bull, who has so carefully preserved the specimens and handed them over to the British Museum, where they will be available to students from all countries. The modern name of the animal is *Hyracotherium leporinum*, Owen, for *Pliolophus vulpiceps* proves to be identical with a species founded in 1841.

THE FOSSIL TRACK OF A DYING LOBSTER.—Dr. J. Walther has remarked that very few of the Crustaceans preserved in the Kimmeridgian Plattenkalk at Solnhofen exhibit traces of a death-struggle or of any movement, and he infers that these and other forms of life were dead before their remains were swept into the basin where the Plattenkalk was accumulated. In *Knowledge* for September Dr. F. A. Bather describes and figures a specimen of *Mecochirus longimanus*, one of the Glyphæidæ, accompanied by tracks indicating the movements that took place during the last few minutes of its life. From the nature and the distinctness of the markings it is inferred that the animal had been thrown on to a mud-flat exposed for a time to the direct rays of the sun. The specimen is numbered I 16137 in the Geological Department of the British Museum.

All Communications for this Magazine should be addressed to

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NOVEMBER, 1914.

CONTENTS.

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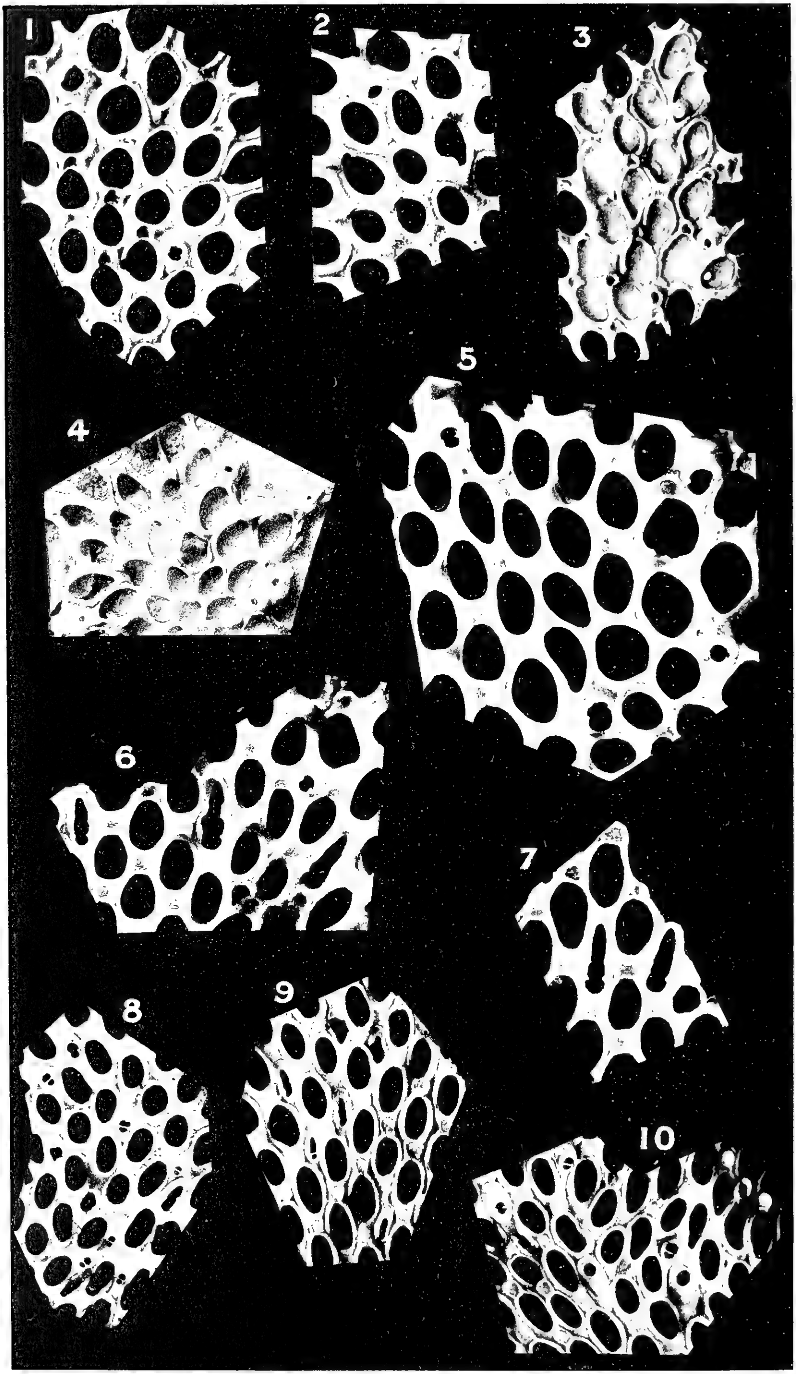


R. M. Brydone, Photo. *Bemrose, Collo.*

Chalk Polyzoa.

THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. I.

No. XI.—NOVEMBER, 1914.

ORIGINAL ARTICLES.

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

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

(*Continued from the August Number, p. 347.*)

(PLATE XXXV.)

A SMALL group of English *Membraniporæ* is strongly characterized by the possession of interstitial avicularia having one end raised into a smooth hood. No described species seems to possess such avicularia, except perhaps the form figured by d'Orbigny as *Membranipora concatenata*.[1]

Membranipora cucculligera, sp. nov. (Pl. XXXV, Figs. 1, 2.)

Zoarium unilaminate, adherent.

Zoœcia fairly large, very slightly pyriform, areas oval, average length ·5 to ·6 mm., breadth ·38 to ·4 mm.; side walls fairly thick, slightly overarching.

Oœcia occurring freely, small, rather shortly globular, with slightly concave free edges lying well back from the margin of the area, the side wall of which is very thin beneath them (Fig. 2).

Avicularia only of the type characteristic of the group, from one-third to one-half the area of the surrounding zoœcia; the lower part is pyriform and embraces the lower half of the aperture in a horizontal plane; the upper part is raised as a hood, the free edge of which rises at a steep angle and is marked off by a shallow furrow; they are fragile, but even badly damaged specimens generally suggest their nature at once.

This species is known only in the zone of *M. cor-anguinum* in Hants and Kent, where it occurs regularly.

Membranipora vestigialis, sp. nov. (Pl. XXXV, Figs. 3, 4.)

Zoarium unilaminate, adherent.

Zoœcia elliptical, wide in the middle, but tapering a good deal at the ends, with very low and very thin side walls looking like mere traces of a more robust form; average length of area ·45 to ·6 mm., breadth ·3 to ·35 mm.

Oœcia numerous and fairly robust, small, helmet-shaped, but slightly rectangular in ground plan, the free edge coinciding with the outline of the area.

[1] Pal. Crét. Franç., tome v, pl. 729, fig. 6.

Avicularia only of the type characteristic of the group, about one-third the size of the zoœcia, numerous, robust, and very prominent, distributed irregularly, but with a strong tendency to succeed oœcia.

This species occurs very sparingly in the zone of *M. cor-anguinum* in Hants and Kent and in the zone of *O. pilula* in Sussex. Above the latter zone the group is entirely unrepresented in my collection until we come to the Trimingham Chalk.

MEMBRANIPORA PRÆCIPUA, sp. nov. (Pl. XXXV, Figs. 5–7.)

Zoarium unilaminate, adherent.

Zoœcia large with fairly thick side walls overhanging very slightly; areas elliptical, average length from ·65 mm. upwards, breadth from ·35 mm. upwards.

Oœcia abundant but delicate, slightly globular, the free edge coinciding with the outline of the area, the side wall of which is exceedingly thin beneath them.

Avicularia of two types—

1. Interstitial, of the type characteristic of the group, nearly as large as the zoœcia and tending to introduce new rows of zoœcia; the hood is straight or even slightly concave in outline at the upper end, and has a free edge embracing the upper half of the aperture and then curving round and backwards to a point of attachment on the outer margin; there are distinct traces of a bar across the aperture just below the hood.

2. Vicarious, long drawn out and very gently curving, extreme instances of the hour-glass type with traces of a bar across the lower end; they are the most graceful and delicate objects that I have met, and the figures do not do them anything like justice.

The vicarious avicularia are extremely capricious in occurrence; the interstitial ones are also rather capricious, but it is very rare for any zoarium of decent size which suggests this species by the dimensions of its zoœcia not to show at least one recognizable, even if damaged, avicularium of this type (Figs. 5, 7).

This species, which is apparently confined to the Trimingham Chalk, seems clearly a descendant or near relation of *M. cuculligera*.

MEMBRANIPORA SACERDOTALIS, sp. nov. (Pl. XXXV, Figs. 8–10.)

Zoarium unilaminate, adherent.

Zoœcia markedly pyriform with slender slightly overarching side walls and narrowly elliptical areas of average length ·5 mm. and breadth ·25 to ·3 mm.; in early stages the zoœcia tend to be broadly elliptical (Fig. 8).

Oœcia very numerous but very delicate, long, and narrow, in ground plan widest at the upper end and tapering gradually downwards, markedly bottle-necked.

Avicularia of two types—

1. Interstitial, of the type characteristic of the group, small, long, and narrow, with the hood very well developed and resembling a monkish cowl, and a bar across the aperture sometimes preserved; the aperture almost invariably faces the centre of the zoarium, the reversed specimens seen in Fig. 10 being quite abnormal. This

type is exceedingly erratic in occurrence; in the very large zoarium from which Fig. 9 is taken they are not as numerous as one per 100 zoœcia, while Figs. 8 and 10 show how numerous they can be in exceptional cases.

2. Sub-vicarious, of the hour-glass type, very narrow, with the covered centre much drawn out and the open ends short and rounded; very rarely a bar across the lower end is preserved. Avicularia of this type are always present in abundance.

The species appears to be confined to the Trimingham Chalk.

EXPLANATION OF PLATE XXXV.

(All figures × 12 diams.)

Fig.				
1.	*Membranipora cucullligera.*	Zone of *M. cor-anguinum.*		Wallers Ash, Hants.
2.	,, ,,	,,	,,	Gravesend.
3.	,, *vestigialis*	,,	,,	Micheldever, Hants.
4.	,, ,,	,,	,,	Gravesend.
5.	,, *præcipua.*	Trimingham.		
6.	,, ,,	,,		
7.	,, ,,	,,		
8.	,, *sacerdotalis*	,,		
9.	,, ,,	,,		
10.	,, ,,	,,		

II.—Fossil Insect in Amber.

On *Stenurothrips succineus*, gen. et sp. nov., an interesting Tertiary Thysanopteron.

By Richard S. Bagnall, F.L.S., F.E.S.

(PLATE XXXVI.)

THE thrips described herein was submitted to me by Professor Branca of the Geologisch-Palaeontologisches Museum, Berlin, and is one of a small collection of three examples in Baltic Amber. The genus is curious on account of the abnormal tube-like development of the tenth abdominal segment, which, however, is open ventrally for its entire length. In the form of the antennæ, so far as can be ascertained from the single example and the structure of the wings, *Stenurothrips* would seem to show affinity with the Neotropical genus *Heterothrips*, and for the present I regard the genus as falling in the Heterothripidæ.

In the generic description I have stated that there is a cross-vein connecting the two longitudinal veins of the fore-wing near the basal third. In this example I *think* I can discern this cross-vein, which is shown somewhat markedly in the figure, but it is open to some doubt. In another species of the same genus now before me, and chiefly separated from the present species by the more minute spines of the fore-wing, the wings are spread out, and this cross-vein is distinctly discernible.

Whilst I have been able, by various lighting arrangements, to obtain a close detailed report of the upper surface, it has been impossible to make out the mouth-parts, the legs, which are tucked under the body, the basal part of tube ventrally, etc., on account of a thick milky cloudiness, which, in a lesser degree, also somewhat obscures the dorsal surface of the abdominal segments 8, 9, and base of 10, so that it is impossible to describe the arrangement of bristles, shown in the figure as springing from segment 9 with absolute accuracy. The angle of the antennæ makes it impossible to gauge the relative lengths of segments.

Order THYSANOPTERA.

Sub-order TEREBRANTIA.

Family HETEROTHRIPIDÆ, Bagnall.

Genus Stenurothrips, nov.

♀ Head transverse, about as long as prothorax. Antennæ nine-jointed, the first four joints stouter than the succeeding five.

Prothorax transverse, two prominent bristles at each hind angle; mid-lateral pair well developed. Pterothorax well developed. Wings long, fore-wing with two longitudinal veins each uniting with the ring-vein near apex; apparently a cross-vein uniting the longitudinal veins near basal third. Costa and both veins set for whole length with setæ.

Abdomen elongate-ovate, with tenth segment abnormally produced, very elongate, cylindrical, open ventrally for entire length, and longer than the length of head and prothorax together. Segment 9 furnished with long bristles, and 10 with a series of setæ before apex. Ovipositor presumably long and straight.

Type: *Stenurothrips succineus*, mihi.

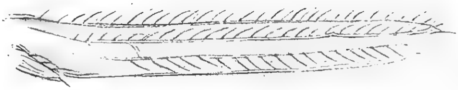
Of living Thysanoptera this form undoubtedly comes near *Heterothrips*, a Neotropical genus, but is strikingly distinguished by the abnormal development of the tenth abdominal segment, the tubiform appearance suggesting a Tubuliferon.

We have noticed several forms distinguished by a similar development, notably *Panchætothrips*, a Heliothripid-like form, distinguished by the form of the explanate margins of abdomen and produced pleurites, and the tube-like tenth abdominal segment, in which there is exhibited a tendency for the ventral opening to close. In this form the ovipositor is styliform and but poorly developed. In *Dinurothrips*, Hood, and *Macrurothrips*, Vuillet, the tenth segment is also strikingly developed.

Stenurothrips succineus, sp. nov.

Length about 1·8 mm., breadth of mesothorax 0·35 mm., length of tenth abdominal segment about 0·35 mm.

Head transverse, about 0·75 as long as broad, and as long as or a little longer than the prothorax. Cheeks sub-parallel, dorsal surface near base faintly striate. Eyes large, moderately closely facetted and apparently pilose; greatest dorsal length equal to about 0·75 the total length of head, and space between eyes about 0·4 the greatest breadth across them. Ocelli moderately large, well separated, posterior ones close to the inner margin of eyes; a pair of minute interocular setæ present. Two pairs of rather long backwardly directed setæ on a line behind eyes, practically equidistant, the



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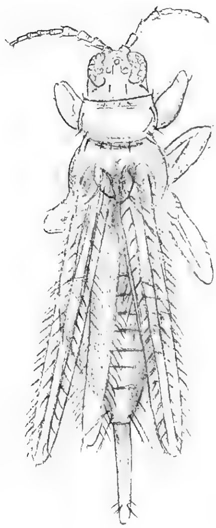

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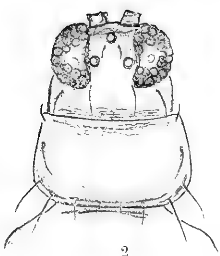

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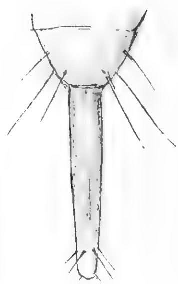

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R. S. Bagnall del.

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STENUROTHRIPS SUCCINEUS *gen. et sp. nov.*

From Baltic Amber.

inner pair being on a slightly higher plane, one near hind angle of each eye. Antennæ nine-jointed, the breadth of the first four joints, which are finely ringed, being noticeably greater than any of the succeeding and 2–4 sub-equal; joints 5–7 fusiform and apparently sub-equal in length.

Prothorax transverse, nearly twice as broad across posterior third as long through middle; anterior angles obtuse, the hind angles broadly rounded. Surface, anteriorly at least, faintly transversely striate. Each hind angle furnished with two long bristles, about 0·6 the length of the prothorax; a mid-lateral pair backwardly (and slightly inwardly) directed and about 0·45 the length of the prothorax. A series of at least two pairs of postero-marginal setæ.

Pterothorax well developed, much broader than prothorax but not quite as broad as the abdomen at broadest. Wings long, about ten times as long as broad near middle, reaching to about the middle of the tenth abdominal segment, apically somewhat pointed; two distinct longitudinal veins running for the entire length of fore-wing, apparently connected by a cross-vein at about the basal third, and each uniting with the ring-vein near tip. Costa and longitudinal veins uniformly set with moderately long stout setæ, the costa with approximately 45, upper vein 23, and the lower vein 18; a single seta set near apex of wing, just beyond fore-vein but not on it. Setæ as long as or longer than 0·35, the breadth of wing near middle.

Abdomen — excluding segment 10 — elongate-ovate, the ninth segment narrowing to base of 10, which latter is exceptionally elongated, a little longer than the length of the head and prothorax together; ventrally open for its entire length and furnished with a series of setæ just before apex. Ninth segment furnished with four postero-marginal bristles, of which the outer pair is apparently longer than the inner and about 0·5 the length of the tenth segment; also furnished with another and shorter dorsal, dorso-lateral, or lateral pair on a higher plane.

EXPLANATION OF PLATE XXXVI.

FIG. 1. *Stenurothrips succineus*, gen. et sp. nov. × 35.
,, 2. ,, ,, Head and prothorax. × *c.* 70.
,, 3. ,, ,, Ninth and tenth abdominal segments. × 70.
,, 4. ,, ,, Underside of tip of tenth abdominal segment. × 70.
,, 5. ,, ,, Right fore-wing. × *c.* 50.

Formation and locality: from Tertiary Lignite Deposits, shores of the Baltic, extending from Dantzig to Memel, etc.

III.—The Principle of Saturation in Petrography.

By S. J. Shand, D.Sc., F.G.S.,
Professor of Geology, Victoria College, Stellenbosch, South Africa.

In a recent number of this journal[1] I advocated the systematic employment of a certain criterion in connexion with the classification and nomenclature of igneous rocks, that criterion being the 'saturated' or 'unsaturated' character of the minerals constituting

[1] Geol. Mag., November, 1913, pp. 508–14.

a given rock. The terms *saturated*, *unsaturated*, and their derivatives *oversaturated*, *undersaturated*, and *partsaturated*, were not used in a strict chemical sense, but in a special mineralogical sense which was fully explained.

Mr. Alexander Scott[1] has criticized my proposal from a theoretical standpoint, and rejects it, but omits to say whether he prefers the 'silica-percentage' type of petrography which it was my aim to supplant. It was not my intention, in writing the paper in question, to offer a complete solution of the most vexed question in petrography, but only to contrast the efficacy of the 'saturation' criterion with that of the silica-percentage as the basis of a descriptive classification. I showed, to my own satisfaction at least, that the former has various advantages over the latter, its easy applicability to the majority of rocks being only one of them. He, however, raises the whole question of the classification of igneous rocks, and subjects my proposal to criticisms which are equally applicable to all propositions for rock classification which have ever been made.

Mr. Scott dreams of a classification which shall "correlate rocks not only of similar chemical composition but also with similar cooling-'histories'". So do we all, and we shall all wish with him success in the search for it. But in the meantime such a classification eludes us, and we must live in a cottage until the palace is ready. It is poor work to destroy without creating, so until he is able to give us something better in exchange for it, we shall beg Mr. Scott (who is only following in the footsteps of Cross and many another) not to pull our present refuge down about our ears. As for my own little contribution, which started this discussion, I regard it in the light of a new beam inserted in the temporary structure in the place of one which, in my judgment, was defective; I have not sought to lay the foundation of a new edifice. When the ultimate classification of rocks is forthcoming, my suggested groupings will disappear from currency (should they ever attain it); nevertheless, I have sufficient confidence in their value to believe that they will not be found irreconcilable with the fundamental principles of that classification of the future.

When one approaches the subject of rock-classification, it is very important to have a clear idea of the aim of classification in general. John Stuart Mill's views on the subject cannot be surpassed for clearness, and the following extracts from his *System of Logic* seem to me to be so especially pertinent to the present subject that I offer no apology for quoting them in a petrographical discussion.

> "Classification . . . is a contrivance for the best possible ordering of the ideas of objects in our minds; for causing the ideas to accompany or succeed one another in such a way as shall give us the greatest command over our knowledge already acquired, and lead most directly to the acquisition of more. The general problem of Classification, in reference to these purposes, may be stated as follows: To provide that things shall be thought of in such groups, and those groups in such an order, as will best conduce to the remembrance and to the ascertainment of their laws.

[1] GEOL. MAG., July, 1914, p. 319.

"The ends of scientific classification are best answered when the objects are formed into groups respecting which a greater number of general propositions can be made, and those more important, than could be made respecting any other groups into which the same things could be distributed. The properties, therefore, according to which objects are classified should, if possible, be those which are causes of many other properties; or, at any rate, which are sure marks of them. Causes are preferable, both as being the surest and most direct of marks, and as being themselves the properties on which it is of most use that our attention should be strongly fixed. But the property which is the cause of the chief peculiarities of a class is unfortunately seldom fitted to serve also as the diagnostic of the class. Instead of the cause, we must generally select some of its more prominent effects, which may serve as sure marks of the other effects and of the cause.

"A classification thus formed is properly scientific or philosophical, and is commonly called a Natural, in contradistinction to a Technical or Artificial, classification or arrangement. The phrase Natural Classification seems most peculiarly appropriate to such arrangements as correspond, in the groups which they form, to the spontaneous tendencies of the mind, by placing together the objects most similar in their general aspect; in opposition to those technical systems which, arranging things according to their agreement in some circumstance arbitrarily selected, often throw into the same group objects which in the general aggregate of their properties present no resemblance, and into different and remote groups others which have the closest similarity. It is one of the most valid recommendations of any classification to the character of a scientific one, that it shall be a natural classification in this sense also; for the test of its scientific character is the number and importance of the properties which can be asserted in common of all objects included in a group; and properties on which the general aspect of the things depends are, if only on that ground, important as well as, in most cases, numerous."

The properties upon which the general aspect of a rock (as distinguished from a rock-body) depends are its mineral constitution and its structure (texture); hence it is not surprising that these properties have from the first been seized upon as being most suitable for the formation of groups. Whatever views one may hold as to the general utility of a classification which is based upon these properties, there can be no question about its being a perfectly 'natural' one, and therefore, according to Mill, a scientific one.

But a school has arisen in later years which demands more regard for chemical composition in our system, and which will not be satisfied with the stock reply that "mineral constitution is a function of chemical composition". Classifications have accordingly been evolved in which mineral constitution is subordinated to ultimate composition, expressed either in molecular ratios or sometimes in mere bald percentages. After much controversy it has generally been conceded that there is reason in both views, and consequently in many recent attempts at classification it has been sought to combine chemical with mineralogical data.

I am in full agreement with Mr. Scott when he states that "These two factors . . . the chemical and mineralogical composition, are the only ones we have for a basis in classification", but when he goes on to assert that they "must be correlated", then I stop short to ask him how he proposes to accomplish it. It is so easy to say "let it be done", so difficult to do it! And Mr. Scott gives us no assistance whatever.

Here is the crux of the whole matter. Anybody who can produce a system in which chemical and mineralogical characters shall be correlated in a satisfactory manner will have solved the great problem of petrography. For myself, having studied the attempts that have been made up to the present time to correlate these properties of rocks, and having myself made very numerous and laborious efforts to accomplish the feat, I have become convinced that nothing is to be gained, but much to be lost, by juggling with these two factors in a hybrid classification.

How can one talk of correlating mineral and chemical composition when one of the commonest of rock minerals shows such a range of composition as the following?—

SiO_2	from	38·41	to	50·08
Al_2O_3	,,	7·07	,,	17·58
Fe_2O_3	,,	0·00	,,	12·42
FeO	,,	0·57	,,	22·22
MgO	,,	2·54	,,	16·31
CaO	,,	9·55	,,	13·75
Na_2O	,,	0·58	,,	3·18
K_2O	,,	0·00	,,	2·18
TiO_2	,,	0·00	,,	10·31

The figures are extracted from Iddings,[1] and the various materials to which the analyses refer are all described as 'hornblende'.

Nephelite is a very definite species to the observer at the eyepiece of the microscope, yet it may hold from 14 to 18 per cent of soda, and from 1 to 7 per cent of potash. The black or brown garnet, which the microscopist identifies as melanite, may range in composition from andradite to schorlomite, and may hold 10 per cent of MnO or Al_2O_3, or 20 per cent of TiO_2, which can only be detected by chemical analysis.

It is clearly impossible for us to isolate and to analyse separately every constituent of a given rock; hence I say that until we discover a means of deducing the chemical composition of such minerals as these from their optical properties, with as much certainty as is attainable in the case of the felspars, no satisfactory expression of the chemical composition of a rock can be made in terms of minerals, or vice versa.

The question whether mineral and chemical composition can be correlated in a satisfactory way is surely answered by the failure of every attempt to perform the operation. Osann's method[2] of building a chemical superstructure upon a mineralogical basis is severely condemned by the American chemical school of petrography,[3] and has not found favour in Britain or France. Iddings, in his most recent work,[4] employs a simple mineral-textural method of grouping and appends to each group a discussion of the chemical composition of the rocks comprised within it. But to do this he must practically make a separate statement of composition for each rock; no general

[1] *Rock Minerals*, 1911.
[2] Tschermaks Min. Pet. Mitt., xix et seq.
[3] Cf. Cross in *The Quantitative Classification of Igneous Rocks.*
[4] *Igneous Rocks*, vol. ii, 1913.

statements can be made, hence there is no correlation. Hatch[1] effects a classification by employing the mineral constitution, as expressed by felspars and felspathoids, and the silica-percentage as abscissa and ordinate in a cross-classification. It is obvious that the method does justice neither to chemistry nor to mineralogy, since all the constituents are not regarded; and furthermore it is easy to show that such a classification makes little advance upon a simple linear classification by felspars alone or by silica-percentage alone, because when the felspars are abundant they largely determine the silica-percentage of the rock. This means that in many cases the two co-ordinates are not independent of each other, hence the purpose of a cross-classification is not attained.

Winchell[2] has recently proposed a classification on three co-ordinates. One of these is mineral constitution, and is chiefly concerned with the kind of felspar present. The second is geological occurrence. The third co-ordinate is the alkaline, peralkaline, or alkalcic (i.e. alkali-calcic) character of the rock as determined (by inspection) from consideration of the relation between alkalies, silica, lime, etc., in all the minerals present. Thus the peralkaline group consists of rocks containing felspathoids; the alkaline group contains chiefly alkali-felspars and alkali-pyroxenes, etc. The third co-ordinate therefore expresses in a rough way the ratio of alkalies to silica, thus—

Alkaline = high alkalies, high silica.
Peralkaline = high alkalies, moderate or low silica.
Alkalcic = low alkalies, moderate or low silica.

This classification consequently affords only a very incomplete and purely qualitative expression of chemical composition.

There are many other classifications which might be passed in review, but it would be waste of ink, for it is matter of common knowledge that, whatever their merits may be, no one of them has ever succeeded in so correlating mineralogy with chemical composition as to satisfy the two opposed schools of petrography. Personally, I have renounced the attempt. I believe it to be impossible. But that does not mean that, in my view, one class of data must be neglected. I believe that both chemical and mineralogical classifications are necessary in order to "give us the greatest command over our knowledge already acquired, and lead most directly to the acquisition of more". And instead of yearning for the unattainable, I should like to see all petrographers trying to agree upon *one* chemical classification and *one* mineralogical classification to meet our present needs. They might not be final, but what of that? They would at least give us a common language in which to compare and record our observations. Apothecaries' weight, based on a grain of corn and other primitive standards, served science well until the metric system was introduced. Fahrenheit and Centigrade thermometers registered the observations which led to the conception

[1] *Text-book of Petrology*, 1909, 1914.
[2] *Journal of Geology*, xxi, 1913.

of the Absolute scale of temperature. If Mr. Scott's arguments were extended to other things besides rock-classifications, nobody would use a lamp, because it is far inferior to daylight, or a taxicab, because it is not an aeroplane.

Although I advocate separate chemical and mineralogical classifications for rocks, it does not follow that the mineralogical classification must be devoid of chemical significance. It must, indeed, divest itself of all attempts to express the percentage composition of rocks in terms of oxides or arbitrarily chosen molecules, but in the act of stating the proportions of various minerals in a rock we unavoidably make some sort of a statement of its composition. Furthermore, the investigation of the proportions which the constituent minerals bear to one another involves the recognition of eutectic proportions, where such exist. If eutectic ratios are to play a part in petrographic system, it is in the mineralogical classification that they will find expression, not in that which deals with ultimate chemical composition. And if there be any other chemical principles in operation, which express themselves in the presence or absence or mutual relations of specific minerals, such principles must be taken into consideration in the construction of the mineralogical groups, since they enable us to make those general propositions which are the soul of a classification.

If the difference between the saturated and the undersaturated rocks bears testimony to the operation of a general principle, namely, that every magma tends to saturate itself with silica, then this difference must find expression in our system. I believe in the reality of the principle just enunciated, basing my belief primarily on the evidence of the rocks themselves. I hold, therefore, that the operation of this principle should govern the mineralogical classification of rocks, and should be apparent in petrographical nomenclature. The degree of saturation is easily observed, except in the case of vitreous rocks, where all mineralogical criteria are equally inapplicable. It is the "sure mark of many other properties", such as the presence or absence of specific minerals, the capacity of the magma to assimilate foreign rocks, and the nature of the reactions thereby induced; furthermore, it throws light on the 'cooling-history' of the magma (which, as I read the facts, generally includes a progressive increase, but sometimes a local decrease, in the degree of saturation), and on the relations existing between the partial magmas or differentiates of an igneous complex. For all these reasons the criterion of saturation appears to me to be one which is eminently adapted to be used in the construction of a mineralogical classification of rocks.

I come now to the more specific criticisms advanced by Mr. Scott. My right to classify olivine as an unsaturated mineral is first questioned. The obvious way to defeat my contention would have been to adduce instances in which quartz and olivine are associated in igneous rocks. Mr. Scott mentions one or two cases of this association, and then plays into my hands by admitting that in one case the olivine, in another the quartz, is "probably xenocrystic". I am pleased indeed to have the additional evidence of Mr. Scott's pitchstone-porphyries from Arran to add to the great weight of observations in favour of my view. We in this country are greatly handicapped in the matter of literature, and the paper in question had escaped my notice. In regard to the quartz-basalts of California and New Mexico, Lacroix[1] has opposed the views of Iddings and Diller, contending, not only on general grounds but also as the result of his own examination of the rocks in question, that the quartz of these basalts is really of foreign origin; he compares the rocks with lavas of Central France in which xenocrysts of quartz and felspar are just as evenly distributed, and yet are clearly of external origin.

Falling short of field evidence, Mr. Scott advances some theoretical considerations against my view. One of these is that the reaction

$$\text{olivine} + \text{silica} \longrightarrow \text{enstatite}$$

may be appreciably reversible under magmatic conditions. If so, where is the evidence of it? It cannot be mere chance which decrees that olivine and enstatite or hypersthene shall commonly occur together, that hypersthene and quartz shall be associated still more frequently, but that quartz and olivine shall never coexist except in circumstances which suggest that one is of extraneous origin. In some cases an olivine-bearing magma has been frozen in the very act of absorbing quartz and developing hypersthene or another pyroxene; numerous instances of this will be found in Lacroix' studies of the reactions between lavas and their inclusions.[2] Mr. Scott has himself explained the appearance of hypersthene in a rock at Garabal Hill by reaction between olivine and quartz.[2] Negative evidence as to the incompatibility of these two minerals is extraordinarily abundant, and he will find some of it at his hand in the intrusions of Kilsyth-Croy, which, according to Tyrrell,[3] contain hypersthene where quartz is present, and olivine only where quartz is absent. Even laboratory work points in the same direction. Daubrée[4] found that when he melted olivine in siliceous crucibles, the melt attacked the crucible with great energy and formed pyroxenes. He concluded from this that the rarity of peridotites in nature is due to the fact that the peridotitic magma tends to dissolve siliceous rocks and so to change its character.

Lastly, Mr. Scott quotes against my view the work of Anderson and Bowen[5]—which comes hot from the printing-press—on the binary system $MgO-SiO_2$. Here at least is evidence worthy of consideration. When a melt of the composition $MgSiO_3$ was cooled down from a very high temperature, *forsterite* was found to crystallize out at about 1,625°, and was followed later by a mixture of $MgSiO_3$ and SiO_2 in the forms of clino-enstatite and cristobalite (probably). But Anderson and Bowen go on to show that forsterite is only produced above 1,557°; when crystallization takes place at any temperature between 1,200° and 1,557°, *only clino-enstatite is formed.* The latter temperature is in fact the point at which clino-enstatite

[1] *Les Enclaves des Roches Volcaniques*, p. 43.

[2] Geol. Mag., November, 1913. [3] Ibid., July, 1909, p. 299.

[4] Cited by Lacroix, loc. cit., p. 498.

[5] Amer. Journ. Sci., xxxvii, and Zeit. Anorg. Chem., lxxxvii, 1914.

transforms into forsterite and glass. It follows from these results that forsterite and free silica can only coexist in a magma which commenced to freeze at some temperature in excess of 1,557°. There is not a shadow of evidence that any natural magma had such an enormously high freezing-point (meaning the point at which freezing commenced). Every one of the common rock minerals whose melting-point is known freezes below 1,550°, and the majority of them much below it. The freezing-point of a magma must therefore be much lower still, in accordance with Raoult's Law, apart from all consideration of the action of 'mineralizers'. Brun [1] and others have shown that the melting-points of fresh lavas lie between 950° and 1,200°; the Palisade diabase of New York [2] is readily fluid, in the crucible, at about 1,200°; Goldschmidt [3] has estimated the maximum temperature which prevailed in contact zones in the Christiania district at 1,000° to 1,200°. The fact is, that instead of disproving my contention, the work of Anderson and Bowen actually proves it by showing that (in a dry melt) forsterite and free silica do not form side by side below 1,557°. Olivine includes fayalite, however, as well as forsterite, and the occurrence of fayalite together with quartz or tridymite in the lithophysæ of acid lavas and the druses of granites has been described by Judd, Lacroix, Iddings, Quensel, and others. Iddings [4] offers the following explanation :—

"... the concurrence of fayalite and quartz in lithophysæ in highly siliceous rocks shows that silicon may be deterred from forming the higher silicate under certain conditions, which appear to be, either those that permit the water present in rock-magmas to enter into combination with the silica, forming a hydrogen silicate H_4SiO_4, which . . . subsequently breaks up into H_2O and SiO_2 which may appear as quartz ; or such that water may act catalytically to promote the immediate separation of quartz before the separation of the olivine compound from the solution."

This is a possible explanation of the conjunction of fayalite and quartz; it would apply especially to the contents of vapour cavities and druses, where magmatic water would be concentrated towards the completion of the freezing of the magma. But a simpler explanation is available which involves no supposition whatever. It is just this, that the compound $FeSiO_3$ is incapable of independent existence under any conditions realized in nature—it is not known as a mineral—hence the lower silicate, fayalite, is stable even in presence of quartz. I ought, on this account, to correct my former lists of saturated and unsaturated minerals by adding the rare fayalite to the former, retaining only the magnesian olivines and forsterite in the latter. The change is a slight one, since practically all common olivine is magnesian and therefore remains on the unsaturated list. Washington, in his recent description of the volcanic rocks of Pantelleria,[5] describes an 'olivine' existing in small amounts in the acid lavas, and shows by analysis that this is a nearly pure fayalite,

[1] *Recherches sur l'exhalaison volcanique*, ch. vi.
[2] R. B. Sosman & H. E. Merwin, Journ. Washington Acad. Sci., 1913.
[3] *Die Gesetze der Gesteinsmetamorphose*, Christiania, 1912.
[4] *Igneous Rocks*, vol. ii, 1913.
[5] *Journal of Geology*, 1914.

not a magnesian olivine. He adds that "the olivine found elsewhere in highly siliceous rocks, as granite and rhyolite, is always fayalite, not common olivine or the magnesian forsterite".

Having disposed of olivine, I pass to Mr. Scott's other criticisms. The possibility of the production of unstable phases, which undergo transformation subsequent to the consolidation of the rock, is urged as likely to render the saturation criterion inapplicable. The alteration of leucite to nepheline and orthoclase is advanced in illustration of this. But the recognitions of such transformations has never presented any special difficulty. Pseudo-leucite is easily recognized as such in most cases, and uralite, serpentine, iddingsite, liebenerite, bastite, pinite, leucoxene, kelyphite, sprenstein, 'chlorite,' saussurite, nearly always betray their parentage. The difficulties which are introduced by such changes affect all mineralogical classifications, and will equally affect the ideal classification of the future. But it is not shown how such a transformation can change a saturated rock into an unsaturated one, or vice versa; hence the argument has no relation to the question at issue.

With regard to the garnets, why does it seem impossible that spessartite and almandite can be stable in presence of excess of silicic acid, while pyrope and melanite are unstable? We have just seen that this very difference exists, within a wide range of temperature, between forsterite and fayalite; and a parallel case can be found in the different behaviour of calcium carbonate and the isomorphous carbonates of magnesium, iron, zinc, and lead towards an excess of carbonic acid. The garnets themselves differ greatly in stability towards mineral acids, some being easily decomposed while others are very resistant. It is probably not too much to say that the end members of most isomorphous series of compounds differ in stability. As regards the effect of pressure on the production of garnets, spessartite is known both in granites and in rhyolites; melanite both in syenites and in phonolites; pyrope both in deep-seated eclogites and peridotites, and in serpentines which may have been lavas. Here is no evidence that the production of garnet requires special pressure conditions. The "observed facts of distribution", in the case of the garnets, are not to be refuted by deduction from such inadequate premises. If I am mistaken in my opinion of the relation of the garnets to silica, then the proof of it exists in the field and should be sought there. At the same time I freely admit that it would be desirable to have experimental confirmation—or refutation—of the unsaturated character of pyrope and melanite.

In conclusion, I see no reason to modify my views regarding the saturation criterion in petrography. Its introduction into the basis of the 'natural' classification of rocks, in conjunction with mineralogical constitution (properly used) and texture, will do something towards giving that classification a meaning and a precision which hitherto have been conspicuous by their absence. And its use will in no way prejudice the reform—or it may be the abolition—of that classification as knowledge advances.

IV.—A NEW CIRRIPEDE FROM THE CENOMANIAN CHALK MARL OF CAMBRIDGE.

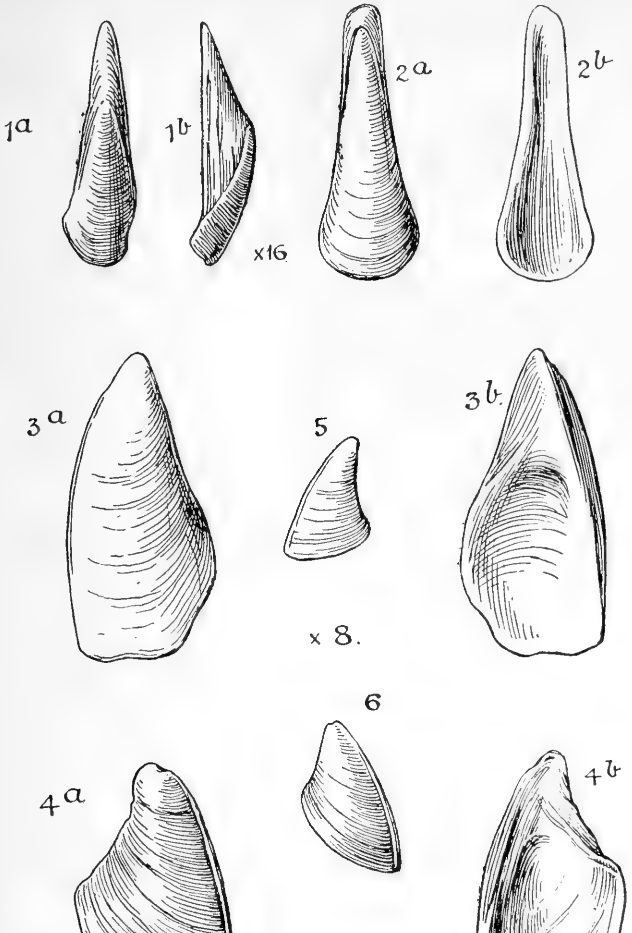
By THOMAS H. WITHERS, F.G.S.

OF the Cirripedes obtained by the late Mr. F. Mockler from the Chalk Marl of Cambridge, two species, *Zeugmatolepas mockleri*, Withers, and *Calantica* (*Titanolepas*) *tuberculata*, Darwin, sp., have already been described and restorations given.[1] The remaining material consists entirely of disconnected valves, and among these are (1) a number of valves referable to *Pollicipes glaber*, F. A. Roemer; (2) a few valves of *P. rigidus*,[2] J. de C. Sowerby, together with some valves of a new species[3] which is probably related to *P. rigidus*; (3) an important series of valves belonging to several species of *Scalpellum* allied to *S. arcuatum*, Darwin, and *S. fossula*, Darwin; and (4) some valves that do not belong to any of the species already mentioned, and which it will be convenient to describe here.

Included in this last series are three minute carinæ and eleven scuta (seven left and four right). I have also a single carina from the Chalk Marl of Burham, Kent, and two scuta (left and right) from the Cambridge Greensand of Cambridge, and these are all precisely similar to the valves from the Chalk Marl of Cambridge. Except for the fact that these carinæ and scuta agree in having their outer surface smooth, and that they were found with a considerable number of valves of other species to which they do not belong, there is no evidence to show that they represent a single species. I am inclined to think that they do, but since they may belong to more than one species, it will be best if we regard the carina as typifying the species. It is noticeable that there are no terga among the valves, but if the terga happened to resemble closely those of *Zeugmatolepas mockleri*, which present considerable variation, there would be some difficulty in separating them. In point of fact, I have attempted to sort out a few valves from the large series of terga of *Z. mockleri*, but, while one could figure extreme valves as belonging to another species, one finds that they grade into other valves, and I have given up the attempt.

The carinæ, of which two from the Chalk Marl of Cambridge have been referred to by me (Proc. Zool. Soc. London, 1912, p. 531), represent the second species to be described from British Cretaceous rocks in which the umbo is in a sub-central position. Previously described Cretaceous species of *Scalpellum* with this advanced type of carina come from the Upper Senonian, so that the occurrence of a similar form so low down as the Cenomanian is especially interesting. I had, however, overlooked the fact that Darwin had already recorded, but not described, a carina from the Cretaceous of England with the umbo in a sub-central position. At the end of his description of the Tertiary *Scalpellum magnum* he says (1851, Pal. Soc. Mon. Foss. Lepadidæ, p. 21): "I may take this opportunity of stating, that

[1] Proc. Zool. Soc. London, December, 1913, pp. 937–48, pls. xciv, xcv.
[2] Ann. Mag. Nat. Hist., ser. VIII, vol. xiv, p. 171, pl. viii, fig. 4, August, 1914.
[3] Tom. cit., p. 187, pl. viii, figs. 7–10.



SCALPELLUM PARVULUM, sp. nov.

FIG. 1. Carina (holotype). *a*, outer view; *b*, side view. Cenomanian, Chalk Marl: near Cambridge.
,, 2. Carina. *a*, outer view; *b*, inner view. Cenomanian, Chalk Marl: Burham, Kent.
,, 3. Scutum (right valve). *a*, outer view; *b*, inner view. Cenomanian, Chalk Mark: near Cambridge.
,, 4. Scutum (left valve). *a*, outer view; *b*, inner view.
,, 5. Scutum (small right valve). Outer view.
,, 6. Scutum (small left valve). Outer view.

Figs. 1–2 × 16 diam.; Figs. 3–6 × 8 diam.

in Mr. Harris's collection of organic remains from the chalk detritus, at Charing, in Kent, I have found the upper part of a carina of a very young and minute *Scalpellum*, which cannot be distinguished from this species [*S. magnum*]; but considering the state of the specimen, it would be extremely rash to believe in their identity. All the known cretaceous species have the umbo at the apex, so that the Charing specimen differs remarkably from its cretaceous congeners." Although search has been made among the Cirripede remains of the Harris Collection from the Charing detritus, now in the Geological Department of the British Museum, the specimen recorded by Darwin cannot be found. It is extremely likely, however, that it belonged to the species here described, since I am of the opinion that the Cirripede material seen by me from the Chalk detritus of Charing is of Cenomanian age.

Scalpellum parvulum, sp. nov.

Diagnosis.—Carina with the umbo situated from just below to about one-third the extent of the valve from the apex, outer surface smooth; apical portion acute and widening gradually downwards to near the basal margin, where the valve is somewhat expanded; tectum and parietes not separated by a ridge; inner margin of intraparietes straight.

Material.—Four minute carinæ, of which the longest measures 2·1 mm., and thirteen scuta, the largest of which has a length of 5·2 mm. and a breadth of 2·4 mm.

Holotype.—The carina (Text-figs. 1*a*, *b*).

Horizon and Locality.—Cenomanian, Chalk Marl: near Cambridge, and Burham, Kent. Cambridge Greensand: near Cambridge.

Description of Valves.—Carina angularly bent, with the umbo varying in position from just below to about one-third the extent of the valve from the apex; the valve is acute at the apex, and widens gradually downwards until near the basal margin, where the valve is rather abruptly expanded; tectum smooth, transversely rounded, not distinctly separated from the parietes; intraparietes wider than half the width of the basal portion of the valve, separated from the parietes by a distinct ridge, and by their upward growth form that part of the valve above the umbo; inner margin of intraparietes straight. Outer surface smooth; inner surface deeply concave, not narrowed under the umbo.

Scutum sub-triangular, outer surface smooth, with an extremely narrow raised rim extending along the occludent margin, and without the slightest trace of an apico-basal ridge; moderately convex transversely, apical portion acute and slightly curved towards the terga. Occludent margin slightly convex; basal margin, in some specimens making almost a right angle with the occludent margin, and in others is sharply upturned and blends into the lower part of the tergo-lateral margin; upper part of tergo-lateral margin slightly concave, and the tergo-lateral angle rounded. On the inner surface the occludent edge is flat and slightly overhangs the rather shallow pit for the adductor muscle; from the tergo-lateral margin, opposite the adductor muscle pit, a slight ridge extends obliquely upwards and inwards to the occludent edge, and above this ridge an obtusely angular portion of the valve is depressed and marked with growth-lines, and evidently served for the reception of the scutal angle of the tergum.

Remarks and Comparison with other Species.—Although the four carinæ of *S. parvulum* are very small, the fact that they are all of about the same size seems to show that they are mature valves. A large amount of material has been carefully looked over, but these four carinæ only were found, so the species is probably rare.

The known Cretaceous species with the umbo of the carina situated sub-centrally number three only, namely, *S. beisseli*, Bosquet and Müller,[1] *S. darwinianum*, Bosquet,[2] and *S. hagenovianum*, Bosquet,[3] one of which *S. darwinianum*, has been described[4] from the Upper Senonian of Salisbury, Wilts. *S. parvulum* is quite distinct from *S. beisseli* and *S. darwinianum*, for in these two species the upward growth of the carina is due to the almost equal upward and downward growth of the valve from the umbo, the parietes and intraparietes are not defined, and the outer surface is ornamented with numerous ridges radiating from the umbo. *S. hagenovianum* agrees in the upper part of the valve being formed by the upward growth of the intraparietes beyond the umbo, but differs among other characters in the intraparietes being ornamented with ridges, and in the tectum being flatly arched transversely with a rounded ridge on either side. The carina of *S. parvulum* resembles more closely that of the Tertiary *S. magnum*, Darwin, but in the absence of the remaining valves of the capitulum it is impossible to say whether the two species are related. In *S. magnum* the inner margin of the carina is markedly concave, and on the inner side the valve is usually narrowed below the umbo, whereas in all the carinæ of *S. parvulum* the inner margin is straight and the valve is not narrowed below the umbo, but widens gradually downwards from the apex and is expanded near the base. Moreover, in *S. magnum* the tectum is separated from the parietes by a ridge, while in *S. parvulum* the tectum and parietes are not defined. Although the absence of a ridge between the tectum and parietes may seem a trivial point, this ridge is clearly seen in quite young valves of *S. magnum.*

As regards the scutum tentatively considered as belonging to *S. parvulum*, it has the umbo at the apex, and therefore differs from *S. magnum*, *S. beisseli*, and *S. darwinianum*, which all have the umbo situated sub-centrally; in its other characters it differs markedly from these and other known species. The scutum of *S. hagenovianum* is not known.

[1] J. Bosquet, *Notice sur quelques Cirripèdes récemment découverts dans le Terrain Crétacé du Duché de Limbourg*, Haarlem, 1857, p. 7, pl. i, figs. 4–7.

[2] J. Bosquet, Monogr. Crust. Foss. du Terr. Crét. du Duché du Limbourg, 1854, p. 46, pl. iii, figs. 6–12.

[3] Tom. cit., p. 49, pl. iv. figs. 13–16.

[4] T. H. Withers, "Some Cirripedes from the Chalk of Salisbury, Wilts": Geol. Mag., Dec. V, Vol. VIII, p. 23, Figs. 3–4.

V.—The Wexford Gravels and their bearing on Interglacial Geology.

By Grenville A. J. Cole, M.R.I.A., F.G.S., and T. Hallissy, M.R.I.A., Geological Survey of Ireland.

I. Introduction.

THE shell-bearing gravels of the county of Wexford have become so well known on account of their fossil contents that the boulder-clays associated with them have received scanty recognition. Very diverse statements have been made in regard to the position of the gravels in the succession of superficial deposits, and they have frequently been confused with the 'marl' which was extolled by early writers upon agriculture. Nearly all the references to the manurial value of such materials in Co. Wexford refer to this marl, that is, to a shelly and calcareous boulder-clay. The gravels, however, have been commonly styled 'manure gravels' by geologists, and R. J. Griffith,[1] as far back as 1836, distinctly states that the shells are sometimes so very numerous "that the gravel is raised for manure".

Numerous 'marl pits', now sometimes overgrown, remain on the farm lands of the county, and their use is well remembered by the people. Their original development is quaintly referred to in Boate's *Natural History of Ireland*[2]—

"The same," i.e. marl, "also is still very usual in sundry parts of England, being of an incomparable goodness: the which caused the English, who, out of some of those places where Marl was used, were come to live in Ireland, to make diligent search for it, and that with good success at last; it having been found out by them within these few years, in several places; first in the King's-county, not far from the Shannon, where being of a grey colour, it is digged out of the bogs; and in the county of Wexford, where the use of it was grown very common before this rebellion, especially in the parts lying near the sea; where it stood them in very good stead, the land of itself being nothing fruitful. For although the ground (for the most part) is a good black earth, yet the same being but one foot deep, and having underneath a crust of stiff yellow clay of half a foot, is thereby greatly impaired in its own goodness. In this depth of a foot and a half next under the clay, lieth the Marl, the which reacheth so far downwards, that yet nowhere they are come to the bottom of it. It is of a blew colour, and very fat (which as in other ground, so in this, is chiefly percieved when it is wet) but brittle and dusty when it is dry."

R. Fraser, in his *Statistical Survey of the County of Wexford*,[3] refers only to the 'marle' as being laid upon the land, and his description makes it evident that this marl was a boulder-clay containing marine shells.

R. J. Griffith (Sir R. Griffith) came across the deposit when engaged in his remarkable geological survey of all Ireland.[4] He notes an "extensive marl deposit in Wexford, some of the shells of which appeared to correspond with those of the crag". A year later he amplified this observation in a presidential address to the Geological

[1] Journ. Geol. Soc. Dublin, vol. i, p. 151.
[2] Edition by Thomas Molineux, Dublin, 1755, p. 57.
[3] Dublin, 1807, pp. 53–5, 76–8, 81, 85.
[4] "On the Geological Map of Ireland": Rep. Brit. Assoc. Dublin, 1835, Transactions, p. 58.

Society of Dublin,[1] when he described, as widely spread in the county of Wexford, a stratum of rolled gravel, 9 to 12 feet thick, "beneath a stratum of calcareous clay marl, of a drab colour." He notes that the shells in the gravel are sometimes very numerous, that the bed is possibly of the age of the Crag of Norfolk, and that the shelly raised beaches of Ireland are distinctly of later date.

T. Oldham, who was in communication with Griffith and with Griffith's colleague, Sir Henry James, emphasized some of these points in 1844,[2] but he apparently added nothing on his own account. Henry James[3] recorded his personal observations in 1846, and defined the Wexford succession as consisting of rolled and waterworn pebbles at the base, then sand, gravel, and drift, the last being considered to be of the age of the northern drift. A large block of coal was found in clays at Rathaspick near Wexford, which Griffith thought was wood-coal from Antrim. E. Forbes named the fossils that were collected, including seventy molluscan species, fifty-five of which are living in British seas. *Fusus contrarius* (*Neptunea contraria*) is said to occur a hundred times more numerously than the right-handed form. E. Forbes visited the Wexford area personally, and published his conclusions and his lists of species in the same year.[4] He states (pp. 377–8) that the shells indicate the parallelism of Newer Pliocene and glacial strata.

Robert Harkness next examined the deposits in 1869.[5] While his conclusions seem to us fully justified, he overlooks several important features in the field. He states, for instance (p. 549), that a Lower Boulder-clay is probably absent in Wexford, and that the gravels have no boulder-clay above them in the sections near the town (p. 544), which is true for certain cases only. He makes the important observation (p. 543) that at Castle Ellis about 40 feet of reddish-brown boulder-clay, with beautifully striated blocks, principally from Cambrian and Silurian strata, overlie the sands and gravels. From this he compares the gravels with those of Howth, which lie between two boulder-clays, and (p. 547) with those of Aberdeenshire and Caithness.

Harkness, with great justice, attributes the flints found in the gravels to some source in adjacent land now worn away. He places this land, however, in the English rather than the Irish Channel. From the nature of the shells he states that the gravels represent a less rigorous climate in Middle Pleistocene times.

E. Hull,[6] fully acknowledging the work of Harkness, placed the Wexford gravels with those of Killiney and Three-rock Mountain

[1] Journ. Geol. Soc. Dublin, vol. i, p. 151, 1837. The address was given on February 10, 1836.

[2] "On the more Recent Geological Deposits in Ireland": Journ. Geol. Soc. Dublin, vol. iii, pp. 62, 66.

[3] "Note on the Tertiary Deposits of the Co. Wexford": ibid., pp. 195–6.

[4] "Distribution of the existing Fauna and Flora of the British Isles, and Geological Changes, etc." (Mem. Geol. Surv. Great Britain), vol. i, p. 336, 1846.

[5] "On the Middle Pleistocene Deposits": GEOL. MAG., 1869, p. 542.

[6] "Observations on the general relations of the Drift Deposits of Ireland to those of Great Britain": GEOL. MAG., 1871, p. 294. Also *Physical Geology of Ireland*, 1878, p. 84; ibid., ed. 1891, p. 112.

near Dublin in his 'interglacial series', a position which he has since consistently maintained. He emphasized the existence of an Upper and Lower Boulder-clay at Killiney, a matter that has since been questioned. The Irish gravels were naturally at that time held to have been deposited in the sea during a temporary depression of the land; but Hull holds strongly that their occurrence indicates a milder climate,[1] after which a partial return of a cold climate produced local glaciers and icebergs. As regards Wexford, he indicates the superposition of an Upper Boulder-clay on the 'manure gravels', while apparently remaining unaware of the existence of the glacial 'marl' below the gravels.

G. H. Kinahan,[2] whose opposition to Hull's views must often be regarded as a matter of principle, promptly recorded his opinion that the Irish gravels lay on no definite horizon. James Geikie,[3] on the other hand, accepted Hull's opinion as to their interglacial character.

Kinahan, in order to emphasize his belief that the glacial series in Ireland was continuous, referred the gravels to the melting of the ice, and the boulder-clay above them to the downwashing and re-arrangement of the earlier glacial accumulations and other material on hill slopes. The Upper Boulder-clay was for him merely 'glacialoid'[4]; and in 1884 (see reference later) he remarked that many of the sands and gravels are probably younger than the material now lying over them. In 1876[5] he again urged that the deposit above the shelly or 'manure' sand of Wexford was not directly originated by ice. About this time he was engaged on the geological survey of Co. Wexford, and he records the succession of deposits far more clearly than any of his predecessors.[6] He relies especially on the coast-sections near Kilmore in the south of the county, and points out the existence of a green sand at the base. Near St. Patrick's Bridge (p. 44) he gives the upward succession as 'marl', 'gravel', and a 'glacialoid drift'; but elsewhere he often records the interlocking of gravel with his glacialoid drift. The green sand, as we shall see later, is not glauconitic, but is a chloritic derivative from the underlying Palæozoic rocks. In a subsequent memoir published in 1882[7] he mentions a thick mass of 'glacialoid' drift as underlying 'manure sand' at Ballynaclash, half a mile south-west of the mouth of the Blackwater. We may say at once that we regard Kinahan's efforts to distinguish a 'glacialoid' drift from boulder-clay as entirely academic, and that

[1] "Observations on the general relations of the Drift Deposits of Ireland to those of Great Britain": GEOL. MAG., 1871, p. 299.

[2] "Middle Gravels (?), Ireland": GEOL. MAG., 1872, p. 267.

[3] "On Changes of Climate during the Glacial Epoch": GEOL. MAG., 1872, p. 105.

[4] "Glacialoid or re-arranged Glacial Drift": GEOL. MAG., 1874, p. 111. On p. 113 Kinahan states that his glacialoid drift occurs above and also interstratified with the Wexford gravels. On p. 172 he allows that local ice may have formed a true drift over gravels in limited areas of Ireland; but he opposes the idea of two separate glaciations.

[5] "Irish Drift. Sub-groups—Aqueous and Glacial Drifts": Journ. Roy. Geol. Soc. Ireland, vol. iv, p. 217.

[6] Geol. Surv. Ireland, Mem. to Sheets 169, 170, 180, 181, 1879, pp. 12–14, 28–51.

[7] Mem. to Sheets 158 and 159, p. 34.

no such discrimination is possible in the field in the areas selected by him as typical. Since he held, in common with most geologists at that time, that the gravels were deposited in a shallow sea, he regarded[1] the boulder-clay above them as an aqueous derivative from islands of the Lower Boulder-clay which stood out above the water.

Kinahan returned to the subject in 1884,[2] and certainly added to the discussion by his clear realization (p. 272) of the conditions that prevail where pure and stone-bearing masses of ice melt away side by side during the decay of a continental ice-sheet.

Since the Newer Pliocene character of the fauna of the Wexford gravels had been emphasized by Forbes (see *ante*), an important remark was made in 1886 by P. F. Kendall & R. G. Bell.[3] Following the stratigraphy established by Kinahan, these authors point out that the Wexford gravels are of Glacial age. In spite of this, A. Bell has since maintained that they are pre-Glacial,[4] and his statements as to the succession of the strata deserve especial mention.

A. Bell is clearly "the writer" referred to in the report on the "Manure Gravels of Wexford", by R. Etheridge, H. Woodward, and A. Bell.[5] It is to be regretted that the associated authors were not in a position to unite in observations in the field. In their first report it is stated that the Wexford gravels are "purely local and bear no marks of ice action, and it is very questionable if this part of Ireland has ever been subjected to glacial action as ordinarily understood". In the second report[6] the succession, in spite of Kinahan's work, is given as "(1) 'manure' gravel series; (2) marls and clays; (3) an illusory or fictitious drift". The marls and clays, which in reality form the base, are said in part to cover the gravels. From pp. 134 and 135 it is clear that the deposit styled an "illusory drift" is identical with that correctly determined by Harkness as boulder-clay abounding in striated blocks.

On p. 138 the section at Killiney in Co. Dublin is discussed, and here an older drift is recognized, with gravels resting on it. The upper portion of the Killiney cliff is unfortunately described as consisting of "smaller gravel".

The third report of the British Association Committee (1889) is merely an *interim* record of progress. The fourth report[7] emphasizes the large number of extinct mollusca in the Wexford gravels (p. 423), as compared with nine other localities of shell-bearing gravels.

In 1892 A. Bell summarized his conclusions.[8] He again (p. 662) makes the remarkable assertion that the series of Wexford sands "rests directly upon Palæozoic rocks and is remarkably free from

[1] Mem. to Sheets 169, etc., 1879, p. 12.

[2] "Note on the Classification of the Boulder-clays and their associated Gravels": Journ. Roy. Geol. Soc. Ireland, vol. vi, p. 270.

[3] "On the Pliocene Beds of St. Erth": Quart. Journ. Geol. Soc., vol. xlii, p. 208.

[4] Proc. Roy. Irish Acad., ser. III, vol. ii, 1892, p. 621.

[5] Rep. Brit. Assoc., 1887, p. 210.

[6] Rep. Brit. Assoc., 1888, p. 133.

[7] Rep. Brit. Assoc., 1890, p. 410.

[8] "Note on the Correlation of the Later and Post-Pliocene Tertiaries on either side of the Irish Sea": Proc. Roy. Irish Acad., ser. III, vol. ii, p. 620.

signs of glaciation". He gives a list of eleven Pliocene and sixteen boreal species out of the total of about one hundred molluscan species recorded, and urges (p. 633) that the facies of the fauna of the marls of Rosslare Bay and Wexford Harbour is entirely different. He states that these marls overlap the sands and are of much later date. Bell's stratigraphical observations must be read with some reserve. His phrase "illusory drift", however, may be taken as a development of Kinahan's ideas.

As the result of a visit to the district for the examination of the soils of Co. Wexford, the present writers were much struck with the confusion still surrounding the stratigraphy of the local drifts. T. Hallissy[1] published a general statement in 1912, and a more detailed account of the succession now follows.

II. The Characters and Succession of the Wexford Drifts.

T. Hallissy has already stated our view (*op. cit.*, p. 178) that the 'marl' of Wexford represents "the englacial moraine of the Irish Sea ice-sheet which invaded this portion of the Wexford area from the north-east". This 'marl' is a chocolate-brown boulder-clay, effervescing on the application of hydrochloric acid. The well-known shelly gravels undoubtedly overlie it, and the loam (Kinahan's 'glacialoid' type and Bell's "illusory drift") that often occurs above these contains numerous striated stones and is identical with Hull's Upper Boulder-clay.

The deposits are widely distributed in the country to the east of the Leinster Chain, but are best developed in the south-east of Wexford, where they attain a maximum thickness of about 60 feet on the coast near Greenore Point; then, thinning towards the west, they occupy a considerable area of the county below the 300 ft. contour-line. As the chocolate clay is a highly calcareous deposit, possessing on an average about 11 per cent of carbonate of lime, it was formerly extensively used as a manure (see *ante*). The shell-bearing gravels likewise are said to have been added to the land with the same object,[2] though there is little traditional evidence to show that this has been the case. At any rate, their use for manurial purposes could not have been very general, as no pits that could have supplied a large quantity of material remain in evidence. Both the chocolate clay and the sands and gravels contain numerous arctic and other shells, occurring mostly in a fragmentary condition, and from the latter deposit some distinctly Pliocene forms have been obtained. In addition, these deposits contain anthracite and bituminous coal, lignite, chalk-flint, jasper, diorite, felsite, red granite, etc. Many striated limestone and sandstone boulders have been found in the chocolate clay, and magnetic iron sand has been obtained from the sands and gravels. The occurrence of the sands and gravels is sporadic, being confined to certain localities situated at intervals over the area, while the 'marl' and non-calcareous loam form practically continuous sheets.

[1] "On the Superficial Deposits of the County of Wexford": Irish Naturalist, 1912, p. 175.
[2] R. Griffith, "Address": Journ. Geol. Soc. Dublin, vol. i, p. 151, 1837.

All three types of drift appear in a 35 ft. section at Crosstown, on the left bank of the Slaney, 1 mile N.N.W. of the town of Wexford. Here the chocolate clay rests on a limestone rock-floor and is overlain by about 6 feet of coarse shelly gravel followed by fine stratified sand, on the top of which repose about 6 feet of non-calcareous stony loam. Both the chocolate clay and the sands and gravels, but notably the latter, contain such considerable quantities of coal that borings or other trials for coal are said to have been made at this locality, though without success. As Griffith pointed out,[1] some of this coal is lignite, like that of Co. Antrim; but a large amount of bituminous coal, and also of anthracite, occurs. Two and a half miles to the north-east of the Crosstown section, at Pollregan, near Castlebridge, is the sand-pit referred to by A. Bell in the second report to the British Association on the "Manure Gravels of Wexford".[2] The pit, yielding good building sand and containing numerous shell-fragments, is situated on a low gravel ridge rising from the general level of the 'marl', which bounds it on every side on the lower ground. Although the stratigraphical relations of the gravel to the other drifts cannot be seen in the actual pit-section, it is fairly safe to infer from its position that it overlies the marl. The superficial drift is absent, at least from the side of the ridge on which the gravel-pit occurs.

Another section studied by Bell is that of Little Clonard, about 2 miles W.S.W. of the town of Wexford. The gravel-pit at this locality yielded many well-preserved shells, and these, as well as the shells from the gravels of neighbouring districts, included some forms of late Pliocene age. This fact led A. Bell to refer the deposit to the same horizon as the St. Erth Beds, which he considers to be a south-eastern extension of the Wexford Gravels. Since he believed the 'marl' to be newer than the gravels, he described the latter as occurring beneath the 'marl' in this section. A careful examination of the section, however, shows that the gravel rests on the 'marl', and is overlain by the non-calcareous stony loam (Upper Boulder-clay), just as in the cliff-section at Crosstown.

The gravels are also well developed at The Deeps, near Killurin. In a new pit at this locality fine and coarse stratified sands are seen resting on the 'marl' as before, and capped by a couple of feet of soil representing the non-calcareous loam of other districts. Magnificent sections of these deposits are exposed for about 4 miles along the coast from Rosslare to Ballytrent, south of Greenore Point, and on the southern coast from Kilmore Quay to Tacumshin Lake. Perpendicular cliffs of drift up to 60 feet in height, which are being rapidly eroded by the sea, are seen in the neighbourhood of Greenore Point. The great bulk of the deposit consists of chocolate clay containing numerous beautifully glaciated boulders, fragmentary shells, coal, flint, jasper, chalk, etc., and at one point it is seen to rest on a glaciated rock-surface with striæ bearing N. 47° E. At other places along this coast the clay overlies a few feet of local

[1] See James, Journ. Geol. Soc. Dublin, vol. iii, p. 196, 1846.
[2] Rep. Brit. Assoc., 1888, p. 134.

rubble, which probably represents the 'head' on the pre-glacial rock-platform which has been noted in this locality.[1] The sands and gravels appear in these cliffs as a coarse gravelly bed near the surface, and in places the loam is represented by a few feet of soil at the top. Some lenses of fine sand were also noted interstratified with the 'marl', and the latter sometimes shows a very delicate lamination, like that referred to by Sollas & Praeger[2] as the 'tea-leaf' type.

The same succession of drifts that has been observed in the sections already described prevails also in the low cliffs along the southern coast from Kilmore eastwards. A section similar to that of Crosstown is exposed at Bastardstown, where the 'marl', the base of which is not seen, underlies some 15–20 feet of stratified shelly sands and gravels, and another section at Ballygrangans exhibits the same stratigraphical succession. In both these cases Kinahan[3] has described the *basal* drift as glacialoid. Both the 'marl' and gravels, like those described from other localities, contain, besides fragmental shells, coal, flint, chert, glaciated limestone boulders, etc., and they normally underlie about 5–7 feet of non-calcareous loamy boulder-clay. The 'marl' is seen to thin out gradually towards the west, and it disappears locally at Kilmore.

A very interesting section was noted in the cliffs at Nemestown, west of St. Patrick's Bridge, near Kilmore, in which the following succession occurs:—

6. Non-calcareous gravelly loam	5 feet.
5. Gravel	9 inches.
4. 'Marl'	5 feet.
3. Ferruginous stratified clay	5 inches.
2. Brownish stratified clay	6 inches.
1. Greenish sandy loam, the base of which is not seen .	2 feet.

The greenish sandy loam, which we may call the 'Nemestown Loam', underlies the marl along this part of the coast; it is sharply differentiated from the superincumbent 'marl', and appears to have undergone denudation before the latter was deposited. Kinahan[4] supposed the Nemestown Loam to be glauconitic in character and similar to the Greensand associated with the English Chalk. A microscopic examination, however, shows that the green colour of the deposit is due, not to the presence of glauconite, but to that of chlorite, which is probably derived from the altered Palæozoic rock (gneiss and slate) on which it rests. The material contains angular fragments of the local rock, lying at all angles in it, and quartz pebbles, possibly derived from Old Red Sandstone, and may represent a pocket of the pre-glacial soil that remained undisturbed by the passage of the great glacier from which the 'marl' was deposited. In the eastern part of Nemestown Strand, the Nemestown Loam and the chocolate marl above it are alike overfolded, no doubt by the

[1] W. B. Wright & H. B. Muff (now Maufe), "The pre-Glacial Raised Beach of the South Coast of Ireland": Proc. Roy. Dublin Soc., vol. x, 1904, p. 300.

[2] *Irish Naturalist*, 1895, p. 321.

[3] Mem. to Sheets 169, etc., 1879, p. 47.

[4] Mem. to Sheets 169, etc., p. 43.

pressure of ice moving from the north-east. On weathering, the chocolate marl shows a distinct lamination.

In spite of occasional loamy bands in the gravels and of gravelly patches in the boulder-clays, we have no doubt that Hull's main contention[1] is correct, and that Wexford, like other parts of Eastern Ireland, records (1) an invasion of foreign ice from the north and north-east, (2) an epoch of recession, which allowed of the formation of shelly gravels as a residual concentrate from the englacial moraine (boulder-clay) which was left behind by the shrinking ice, and (3) a second boulder-clay, in which local rocks are conspicuous, and which represents a return of colder conditions and an extension of the Irish ice.

We agree with Kinahan and Wyley[2] that the flints found in the Wexford drifts were derived from a region of chalk which once stretched across the Irish Sea and the English Channel. Recent work[3] clearly shows how much Cretaceous material has been lost during the formation of the North Atlantic and its eastern inlets. The beach east of Kilmore contains numerous large and almost unrolled flints, which probably come from chalk that still remains in the floor of the adjacent sea. They are larger and fresher on their surfaces than those found in the chocolate clay. The coal that is so abundant in this clay near Wexford town is no doubt derived from the waste of Carboniferous strata, while the lignite, which is found also at Kill of the Grange in Co. Dublin,[4] may represent a widely spread Cainozoic stratum, and is of too frequent occurrence to be attributed to the beds of Co. Antrim.

The Pliocene shells, on which A. Bell has laid such stress, are no doubt also derivative. The Pliocene sea, of which the St. Erth Beds are a record, is held to have formed the plane surface of northern Cornwall,[5] which clearly corresponds with that of South-East Ireland. The finding of iron-stained shells in the drift of Co. Carlow has been cited[6] as fair evidence of the existence of Pliocene deposits in Ireland, which have been concealed by the boulder-clays, or which have been worked up later into them.

There can be little doubt that the shells of the Wexford gravels have all been derived by concentration from the chocolate boulder-clay that was deposited from the Irish Sea ice. The same is true of the stony materials that form the gravels. Any of these materials may in turn have found its way into the later boulder-clay which overlies both the gravels and the chocolate clay; but this later boulder-clay is far richer in subangular blocks of local origin.

[1] *Phys. Geol. Ireland*, 1878, p. 84.

[2] Mem. to Sheets 169, etc., 1879, p. 13.

[3] G. A. J. Cole & T. Crook, "Rock-specimens dredged from the Floor of the Atlantic" (Mem. Geol. Surv. Ireland), 1910. A. Jukes-Browne, *Building of the British Isles*, 1911, fig. 53.

[4] W. J. Sollas & R. Ll. Praeger, "Notes on Glacial Deposits in Ireland. II. Kill o' the Grange": Irish Naturalist, 1895, p. 321.

[5] H. Dewey, Proc. Geol. Assoc., vol. xxv, p. 173, 1914.

[6] G. A. J. Cole, "The Problem of the Liffey Valley": Proc. Roy. Irish Acad., vol. xxx, sect. B, p. 11, 1912.

We may now compare the Wexford Series with that in Co. Dublin, on which Harkness[1] and Hull[2] so largely based their threefold division of the Irish drifts.

III. Comparison of the Wexford Drifts with those near Dublin.

Mainly in consequence of the work of G. W. Lamplugh,[3] the shelly gravels near Dublin are now regarded as the product of local melting of glacier ice, and of the consequent washing away of the finer particles as the englacial matter was set free. The shells in them have been carried, with the Lower Boulder-clay, to their present sites by movements of the ice. Maxwell H. Close, while holding that the gravels represented a submergence, was wont to say that the molluscs had certainly not lived in the beds in which they now are found. They are, in fact, concentrated from a shelly boulder-clay, that is, from the englacial burden brought in by the Scottish ice from the Irish Sea.

The unwashed boulder-clay of this Scottish ice is typically seen in the brick-pits at Kill of the Grange, 1 mile south-west of Kingstown. This deposit and its shelly contents have been fully described by Sollas & Praeger,[4] who state (p. 327) that, though it rests on granite, only one pebble of granite was found among 129 stones collected. A northern origin is assigned to this deposit. J. R. Kilroe in the Survey memoir on the country around Dublin states[5] that the Kill of the Grange clay is older than the Killiney sands and gravels, and than the layers of boulder-clay interstratified with them.

The Kill boulder-clay, which is also well seen in pits nearer to Cabinteely, is greyish to chocolate brown, and strikingly recalls the lower 'marl' or boulder-clay laid down by the Irish Channel ice in Wexford. The fact that it similarly effervesces with acid has not, we believe, been previously noticed. Lignite occurs in it in fair abundance, doubtless from some source now covered by the sea.

Such very different statements have been made about the neighbouring section in the sea-cliff below Killiney station that we might well hesitate to express an opinion here. But we find a marked difference between the chocolate clay, containing few stones, which is revealed at the base towards the south end of the section, and the boulder-clay with large blocks of local granite that overlies the gravels.[6] An overthrust, probably due to the pressure of ice lying somewhere towards Bray, and slipping northward during the epoch of melting, has pushed up the chocolate clay over a portion of the stratified gravels; but the three deposits seem to us sufficiently distinctive, and to support the triple classification long ago advocated by Hull. It cannot be a matter of accident that the chocolate clay,

[1] "On the Middle Pleistocene Deposits": Geol. Mag., 1869, p. 542.
[2] Op. cit., Geol. Mag., 1871, p. 294.
[3] Mem. to Sheet 112, 2nd ed., 1903, p. 45.
[4] Op. cit., *Irish Naturalist*, 1895, p. 321.
[5] Mem. to Sheet 112, 2nd ed., 1903, p. 108.
[6] Hull's view that this is a true boulder-clay (letter in Geol. Mag., 1872, p. 335) has been supported by all recent writers.

which so closely resembles that of Wexford, effervesces when touched with acid, while the matrix of the Upper Boulder-loam gives no reaction.

Mr. W. D. Haigh, A.R.C.Sc.I., has made the following determinations for us in the laboratory of the Geological Survey of Ireland:—

PERCENTAGE OF CALCIUM CARBONATE IN CHOCOLATE CLAY.

Greenore Point, Co. Wexford	9·83
Rosslare, Co. Wexford	12·97
Killiney, Co. Dublin	11·15
,, ,,	10·56
Kill of the Grange, Co. Dublin	11·80
Rochestown Avenue, near Cabinteely, Co. Dublin	9·76

The continuous sections in the county of Wexford are more imposing than those of Dublin; but enough is still seen at Killiney to justify a comparison, and, we believe, an accurate correlation.

We thus find ourselves in disagreement with Kinahan, who denies the existence of an Upper Boulder-clay at Killiney[1]; in agreement with Lamplugh, who accepts an Upper and a Lower Boulder-clay with gravels between them; but in disagreement with Lamplugh and Kilroe,[2] when they minimize the importance of the lower clay and regard it as a mere interlamination in the gravel series. Nor can we agree with Kilroe that the red colour of this clay is due merely to 'progressive weathering'. The sections in the county of Wexford produce a very different impression.

It is noteworthy that the clay brought from the North Sea over the east of England by the great extension of ice from Scandinavia is characteristically of a reddish buff colour.[3] This may be the colour of submarine sediments that became incorporated in the ice-sheet, though O. B. Böggild[4] states that a brown tint is very rare in such deposits if they are of terrigenous origin. Böggild regards the brown colour of such sediments as due to an oxidizing action of the sea on deposits that would ordinarily be grey or blue or green. Fritz Heim,[5] in his examination of specimens from the Atlantic, concludes that red clays are not necessarily derived from the clays of other tints that underlie them, but represent a stage when the area happens to be far from land. He suggests that a difference of colour in the deposits at any one spot indicates a tectonic change. Hans Spethmann[6] states that in the Baltic, off south-eastern Sweden, a chocolate colour is associated with a high percentage (some 13 per cent) of calcium carbonate; but his tables do not bear this out for other areas.

1 "Middle Gravels (?), Ireland": GEOL. MAG., 1872, p. 265.

2 Mem. to Sheet 112, 1903, pp. 40, 104.

3 P. G. H. Boswell, "On the occurrence of the North Sea Drift": Proc. Geol. Assoc., vol. xxv, p. 150, 1914.

4 "Mémoire sur les sédiments sous-marins": Crosière océanographique de la Belgica dans la Mer du Grönland (Bruxelles, 1907), p. 6. Also Report on the Danish Oceanographical Expeditions 1908–10 to the Mediterranean, p. 259.

5 "Bericht über die Grundproben": Zeitsch. Ges. Erdk. Berlin, 1912, No. 2.

6 "Studien über die Bodenzusammensetzung der baltischen Depression": Wissen. Meeresuntersuchungen, Kiel, Bd. xii, p. 313, 1910.

IV. An Interglacial Epoch in Ireland.

It would not have been surprising if the outlying region of the British Isles, exposed to considerable precipitation, had revealed no evidence of an interglacial epoch. While considerable shrinkage was going on in the Scandinavian ice-mass, the central parts of Ireland may have remained covered by a stagnating glacier, which melted so slowly that it was still in existence when glacial conditions again set in. We cannot, however, overlook the evidence of extensive melting, of the flow of broad bodies of water, and of the washing and denudation of the boulder-clay deposited by the ice which descended from Scotland along the Irish Sea. The deposition of that boulder-clay implies the reduction of the great glacier by melting from its surfaces. The waters from the residual masses swept across the moraine matter, which till then had been englacial, and gave rise to the Wexford gravels and their associates along the eastern coast.

The later boulder-clay represents the spread of Irish glaciers during an epoch which failed to reproduce the conditions of the previous ice extension. The large blocks of Leinster granite, which are so well seen in the new cuttings for the Dublin and South-Eastern Railway near Shankill, and which are so frequently observed in other places on both sides of the Leinster Chain, are among the most distinctive features of the second morainic sheet.

Harkness [1] observes that the Wexford gravels represent an epoch of less rigorous climate in Middle Pleistocene times. While Hull calls the Dublin gravels interglacial, and Praeger & Sollas [2] observe that they mark "a great change of conditions", Lamplugh states that they were formed during a recession of the ice.[3] The difference between these authors is evidently one of degree. The same relative positions are taken by those who advocate and those who deny that glaciers are great agents of erosion. No one really overlooks their erosive action, and the question becomes one of how many metres may be removed from a valley-floor during an ice age of unknown duration. The evidence in Ireland for the disappearance of the Scottish ice, whether from Antrim and Londonderry or Dublin and Wexford, is clear enough. The question is, could the local ice at the same time have undergone a great extension, or was there an interval which may be fairly styled interglacial? [4] If cold is the main factor in the production of a glacial epoch, warmth must be the main factor that brings it to an end. Changes in the amount of precipitation cannot be involved in this case. If glacial cold prevailed during the formation of the Wexford and Dublin gravels, the water necessary for their production could not have existed in the liquid state.

English geologists are meeting with the same question in the survey of their eastern drifts. While G. W. Lamplugh consistently maintains

[1] "On the Middle Pleistocene Deposits": Geol. Mag., 1869, p. 549.

[2] "Notes on Glacial Deposits in Ireland. I. The Bray River": Irish Naturalist, 1894, p. 198.

[3] Mem. to Sheet 112, 1903, p. 45.

[4] Cf. G. A. J. Cole, "Glacial Features in Spitsbergen in relation to Irish Geology": Proc. Roy. Irish Acad., vol. xxix, sect. B, p. 207, 1911.

that the British evidence shows only local features due to melting,[1] F. W. Harmer[2] believes that "a considerable interval" may have separated the invasion of the Scandinavian ice from the epoch of local glaciation. P. G. H. Boswell[3] agrees with Lamplugh that the middle sands and gravels of Eastern England represent a vicissitude, but not a "mild Interglacial Period". We venture to think that these authors, had they lived in early Pleistocene times, would have welcomed an epoch of rain and fluvioglacial flooding, with the temperature above 0° C., like that of summer in Spitsbergen, after the aerial hoar-frost and dry ice-surfaces of an ice-age, and would have felt that the new conditions could no longer be described as glacial. The Wexford gravels have already played their part in controversy. This fresh examination of them may prove of service in bringing that controversy to a close.

VI.—The Zone of *Offaster pilula* in the South English Chalk.

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

(*Continued from p. 457.*)

IV. General Conclusions.[4]

I CLAIM to have now shown that the zone of *O. pilula* as established in 1912 for Hants and the Salisbury area holds good in its broad features also for Sussex, the Isle of Wight, and Dorset, and that it is almost equally constant in some of its minor features, especially the way in which it ends in a bed 2 ft. 6 in. to 3 feet thick with a flint seam in the middle of it and enclosed by two marl seams. I am only prevented by a single section in Hants from setting this up as the universal rule in all sections I have seen. In *The Stratigraphy* I assigned pits Nos. 1065, 1066, and 1067, the last of which will be more readily recognized as Mottisfont Whiting Pit, to the zone of *A. quadratus*, because on examining them for the purposes of that work for the first time since 1892 I had failed to find evidence of more than a seam of *O. pilula* without any others of the associated fossils of the zone. At the time of that examination all the pits were in a most unfavourable condition. Since then I have been keeping regular watch on the Whiting Pit (No. 1067), and I soon found that the subzone of abundant *O. pilula* must be represented at its base, and then that the upper belt of *O. pilula* in that subzone must be exposed:[5] but it was only this spring that I was able to fix the absolute position of the

[1] "The Interglacial Problem in the British Islands"; paper printed at the Congrès géol. internat. at Toronto, 1913.

[2] Discussion on paper by P. G. H. Boswell, Quart. Journ. Geol. Soc., vol. lxix, p. 581, 1913.

[3] "On the occurrence of the North Sea Drift": Proc. Geol. Assoc., vol. xxv, p. 129, 1914.

[4] Part I appeared in the August Number, pp. 359–69; Part II, September, pp. 405–11; Part III, October, pp. 449–57.

[5] The specimen of *A. verus* recorded from this pit and assigned to the zone of *A. quadratus* in *The Stratigraphy of the Chalk of Hants*, p. 99, may therefore have come from the uppermost beds of the zone of *O. pilula*; but the odds are in favour of the zone of *A. quadratus*, which occupies three-fourths of the pit.

boundary between the zones of *O. pilula* and *A. quadratus* in the Whiting Pit, and at the same time, owing to developments in the other two pits, to identify the *cinctus* belt in the old face and the lower belt of *O. pilula* in the new workings (and probably also at the lowest point of the old face) of Pit No. 1066, and the lower belt of *O. pilula* at the base of Pit No. 1065. The bed, which at the Whiting Pit ends the zone of *O. pilula* and contains the typical Offasters of exceptional size and shape, is enclosed by marl seams, but differs from the corresponding bed in all my other exposures in being 4 feet thick, hard, full of sponge remains, and devoid of flints, and the whole upper part of the subzone is notably poor in fossils and flints as compared with other Hampshire sections. I suspect that these variations indicate that Mottisfont was within the radius of the exceptional influence which must have been at work in the neighbourhood of Salisbury, which is already known through Dr. Blackmore for such striking abnormalities as the absence of *A. granulatus* at all horizons, and a concentration of *Belemnitella lanceolata* a few feet above the zone of *O. pilula*. It is therefore to be anticipated that in the Salisbury area the zone of *O. pilula* will be recognizable by its broad features; but correspondence in minute details is not to be expected.

Unfortunately it is an open question whether the zone I have defined can continue to bear the name of "zone of *O. pilula*". That name was preoccupied by the late Mr. Jukes-Browne in a paper published in the Geological Magazine for July and August, 1912, entitled "The Recognition of two Stages in the Upper Chalk", for a conception which was only defined piecemeal in this paper and a subsequent one in the Geological Magazine for April, 1913, entitled "The Division of the Upper Chalk". It was to correspond in Hants with the subzones of *E. scutatus* var. *depressus* and *O. pilula* as proposed by Mr. Griffith and myself in *The Zones of the Chalk in Hants*. In Sussex it was to embrace at least all the chalk above the zone of *Marsupites* exposed in the cliffs. In Yorkshire it was to embrace at least all the chalk above the zone of *Marsupites* exposed in the cliffs. But for each county he used a different test. The one he applied in Hants was quite vague, as the subzones on which he relied had at that time no defined boundaries except the lower boundary of the subzone of *E. scutatus* var. *depressus*; but it has since become most definite through the determination of these boundaries by me in *The Stratigraphy of the Chalk of Hants*.

The test which he applied in Sussex is clearly the periodical recurrence of bands of *O. pilula*, coupled with the occurrence of *A. granulatus*. Whether the Chalk of Sussex which he assigns to his zone responds to his test depends on the accuracy of the statement that "*O. pilula* is common at intervals *throughout* the 170 feet exposed in the cliff between Seaford and Brighton, while *A. granulatus* occurs through at least the lower 150 feet" (the italics are mine). This statement, so far as it relates to *O. pilula*, is accurately paraphrased from Dr. Rowe,[1] but as to half the Chalk in question its truth is, at any rate, highly debatable. So far as the statement

[1] *Coast Sections*, i, p. 342.

relates to *A. granulatus* it is presumably based on the Belemnite mentioned by Dr. Rowe[1] as found 150 feet above the zone of *Marsupites*. But Dr. Rowe does not state that this Belemnite was identifiable as *A. granulatus*; on the contrary, he states that it was not identifiable, but was considered to resemble *A. quadratus* and to be likely to be that species. Clearly, therefore, Mr. Jukes-Browne's test, even if a sound one, does not justify his assigning 150 feet positively, with a further 20 feet, as stated by him (really about 50 feet), by inference to his zone of *O. pilula*. On the other hand, the two specimens of *A. granulatus* 120 feet above the zone of *Marsupites*, recorded by Dr. Rowe on the same page, compel the assignment to Mr. Jukes-Browne's zone of *O. pilula* a minimum thickness of 120 feet. This is already 15 feet more than can respond to my zone of *O. pilula*, and the discrepancy is liable to be increased at any moment by the finding of *A. granulatus* at higher levels. The truth is that the granulated Belemnites are too scarce in South England in the middle of the *old* zone of *A. quadratus* to be treated as normal constituents of the fauna, when the enormous area exposed at this horizon in the cliffs of Sussex and inland in Hants is considered. At the moment of writing there are only thirteen accurately zoned and reliably identified specimens known to me from Hants and Sussex. They are distributed as follows:—

	A. granulatus.	Intermediate forms.	*A. quadratus.*
Chalk of zone of *A. quadratus* whose position can be fixed by reference to the zone of *O. pilula.*	Two in Sussex, 15 feet above zone of *O. pilula.*	—	One in Sussex, 8 feet above zone of *O. pilula.*
Subzone of abundant *O. pilula.*	—	—	Four in Hants. One in Sussex.
Upper part of subzone of *E. scutatus* var. *depressus.*	—	Two in Sussex.	One in Hants.

Note.—Two of the Sussex Belemnites have been found since the Sussex section of the paper went to press.

To these it may be added on Dr. Blackmore's authority that at Salisbury *A. granulatus* is not yet known at any of these horizons, which have been extensively worked, but two specimens of *A. quadratus* have been found in the lower belt and three in the middle belt of the subzone of abundant *O. pilula*, while in the upper belt of this subzone *A. quadratus* becomes definitely an established member of the fauna. Now that the range of this upper belt of the subzone has been established at Mottisfont, where it undoubtedly contains a fair number of granulated Belemnites, there should very soon be further evidence available from there.

Obviously the material is at present hopelessly inadequate to support even in theory the establishment of a zonal boundary for

[1] *Coast Sections*, i, p. 343.

South England dependent on the range of *A. granulatus*; and it is impossible that such a boundary should ever be practicable in the field.

For Yorkshire Mr. Jukes-Browne's test is the presence of *A. granulatus.* There is nothing to my knowledge which justifies an assumption of correspondence between my zone of *O. pilula* in South England and all Yorkshire Chalk (above the zone of *Marsupites*) which contains *A. granulatus.* There is not even yet any evidence that *A. granulatus* has in Yorkshire the definite and constant range which it should have if its range is to determine a zonal boundary, much less that, if it has such a range, that range corresponds with a zone. Assuming that it has in Yorkshire a definite upward range, it is equally possible to argue that the Yorkshire range of *A. granulatus* is larger than my zone of *O. pilula* because the South England range of *A. granulatus* is larger than my zone of *O. pilula*, and to argue that the Yorkshire range of *A. granulatus* is less than my zone of *O. pilula* because in South England an interruption of the range of *A. granulatus* and apparently a passage of *A. granulatus* into *A. quadratus* take place in the middle of my zone of *O. pilula.*

The net result is that Mr. Jukes-Browne's zone of *O. pilula* is not identical with mine; and if his stands mine must fall.

Study of the zone of *O. pilula* inevitably draws attention to the remarkable differences between districts in the matter of marl in the Upper Chalk. The Hampshire student would leave that county convinced that above the zone of *M. cor-testudinarium* marl is an anomaly except for the subzone of abundant *O. pilula* and the zone of *B. mucronata.* Even the subzone of abundant *O. pilula* seems to be free of marl in the *cinctus* belt in Hants.

He would be surprised on reaching the Sussex coast to find that while the zones of *M. cor-anguinum* (apart from the *Uintacrinus* band) and *A. quadratus* were still practically devoid of marl, marl seams set in at the base of the *Uintacrinus* band and occurred at frequent intervals throughout that band and the zones of *Marsupites* and *O. pilula*, and he would find the same state of things in Dorset, though with a marked reduction in the extreme west at Middle Bottom in the degree of marliness. (It is curious that Dr. Rowe should have described the zone of *O. pilula* at Cockpit Head, which is full of marl seams, as "free from marly veins and bands".) In the Isle of Wight he would at last find the zone of *A. quadratus* beginning to give way to marliness at Culver Cliff and substantially affected by it at Scratchells Bay, though even here the zone of *M. cor-anguinum* still retains its character for purity. The obvious explanation, which I have heard given, is that the marl was introduced by currents. This explanation is quite inadmissible. No muddy current breaking into a calm sea could possibly spread itself so uniformly over such great distances as to deposit these exceedingly thin layers for the miles and miles for which they can be traced with certainty, and the far greater distances for which some of them, such as the marl seam which closes the zone of *O. pilula*, can be inferred to run without a break. To distribute itself in this way the current would require a speed and volume which would have swept the sea bottom into chaos, and it must have been shut out whenever a marl seam gives place to chalk, and reintroduced whenever chalk is succeeded by a marl seam. The only possible explanation I see is that in the path of the prevailing wind, but a great way off, there lay a region of great but intermittent volcanic activity, and that the marl is wind-borne volcanic dust. Under these conditions there might easily be produced the thin sharply defined marl beds deposited continuously and in practically unvarying thickness over large areas at irregular intervals, which we actually find. The large quantity of marl that may be present in seams even in most typical 'White Chalk' is a point which seems not to have been realized by those who argue that the residue after solution of even a considerable thickness of 'White Chalk' *could* not suffice to produce the 'Clay with Flints'.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science, Eighty-fourth Annual Meeting, held in Australia, August, 1914. List of Titles of Papers read in Section C (Geology), etc.

(At Melbourne.)

Professor E. W. Skeats.—The Geology of Victoria.

Dr. T. S. Hall.—Victorian Graptolites. (p. 468.)

Joint Meeting with Section E on the Physiography of Arid Lands, opened by Sir Thomas H. Holland. Speakers: Professor T. W. Edgeworth David, Professor W. M. Davis, Professor J. W. Gregory (p. 419), Dr. W. F. Hume (p. 421), Professor J. Walther (p. 424), and others.

Mr. Ellsworth Huntington.—The Causes of Aridity in Post-Geological Times and the Bearing of this on Present Conditions.

Prof. E. W. Skeats.—On the Tertiary Alkali Rocks of Victoria. (p. 470.)

Dr. H. S. Summers.—On the Origin and Relationship of the Victorian Kainozoic Alkali Rocks. (p. 472.)

Dr. H. T. Jensen.—The Origin of the Alkali Rocks.

Mr. H. T. Ferrar.—The Permo-Carboniferous Breccia, a Desert Formation. (p. 465.)

Mr. H. T. Ferrar.—The Occurrence of Loess Deposits in Egypt. (p. 421.)

Professor A. P. Coleman.—The Climatic Conditions of the Early Pre-Cambrian. (p. 466.)

Mr. F. Chapman.—On the Age and Sequence of the Tertiary Strata of South-Eastern Australia. (p. 514.)

Dr. T. S. Hall.—Discussion on the Age and Sequence of the Victorian Tertiaries. (p. 517.)

Dr. G. B. Pritchard.—Discussion on the Age and Sequence of the Victorian Tertiaries. (p. 519.)

Professor J. W. Gregory.—The Correlation of the Australian Marine Kainozoic Deposits: Evidence of the Echinoids, Bryozoa, and some Vertebrates. (p. 516.)

Mr. D. J. Mahony.—The Evolution of Victoria during the Kainozoic Period. (p. 469.)

Mr. H. Herman.—On the Tertiary Brown Coal-beds of Victoria. (p. 466.)

Reports of Research Committees.

(AT SYDNEY.)

Presidential Address by *Sir T. H. Holland.* (See *ante*, pp. 411–18, 457–64.)

Joint Meeting with Sections D, E, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.

Mr. Frank Debenham.—The Sedimentary Rocks of South Victoria Land. (p. 467.)

Dr. A. Smith Woodward.—The Old Red Sandstone Fishes of Australia.

Mr. W. S. Dun.—The Palæozoic Coral Faunas of Eastern Australia.

Professor T. W. Edgeworth David and *Mr. W. S. Dun.*—On the term Permo-Carboniferous and on the Correlation of that System. (p. 468.)

Mr. E. C. Andrews.—The Post-Jurassic Geography of Australia. Notes on the Hypothesis of Isostasy. (p. 520.)

Mr. S. Dunstan.—The Geological Relations of the Artesian Water-bearing Beds of Southern Queensland.

Mr. E. F. Pittman.—The Great Australian Artesian Basin and the source of its supply

Mr. W. N. Benson.—The Occurrence of Spilitic Lavas in New South Wales.

Mr. C. A. Sussmilch.—The Metallogenetic Provinces of Eastern Australia.

Mr. L. A. Cotton.—The Genesis of the Diamond in New South Wales.

Professor E. S. Moore.—Structural Features of the Coal-fields of Pennsylvania. (p. 523.)

Reports of Research Committees: Ramsey Island, Pembrokeshire. (p. 522.)

Section K (BOTANY). (At Sydney.)

Professor A. C. Seward.—(1) The Vegetation of Gondwanaland. (2) The Older Mesozoic Floras of the World.

II.—*Papers read in Section C (Geology), Meeting of British Association, Australia, August, 1914.*

(1) ON THE AGE AND SEQUENCE OF THE TERTIARY STRATA OF SOUTH-EASTERN AUSTRALIA. By FREDERICK CHAPMAN, A.L.S., Palæontologist to the National Museum, Melbourne.[1]

Divisions of the Kainozoic.—It is convenient to divide the Australian Tertiary system into four or five main series, using the local terms suggested by Hall and Pritchard. In ascending order, these, according to the writer, are: (1) Balcombian, (2) Janjukian, (3) Kalimnan, (4) Werrikooian. Above these comes the Pleistocene Series, referred by many geologists elsewhere to a separate system, the Quaternary. These divisions, broadly speaking, correspond with: (1) Oligocene, (2) Miocene, (3) Lower Pliocene, (4) Upper Pliocene.

The present writer maintains that, giving due allowance to time discrepancies in regard to the factor of distribution of life-forms over wide areas, guide fossils are probably as important in dividing and

[1] See also under Reviews, p. 526.

allocating these beds to the well-known horizons of the northern hemisphere as are percentages of living forms in these fossil deposits. The percentage method can only be used with safety as an approximate guide to age, seeing the difficulty of obtaining an agreement amongst zoologists as to what constitutes a species.

The above series of European divisions correlated with the Australian corresponds almost exactly with McCoy's original determinations, augmented by observations on faunas and stratigraphic relationship of the beds made by the writer during twelve years' attention to this subject.

Sequence of the Beds.—With regard to the sequence, some Victorian authors hold the opinion that the Janjukian Series is older than the Balcombian ; but the confusion seems to have arisen from the occurrence of a large number of persistent species, especially of Mollusca, passing up from the argillaceous Balcombian into the Janjukian Clay Series. Where faunistic and stratigraphic relationships were both doubtful the term Barwonian was suggested, which included both Balcombian and Janjukian. If, however, we regard the scope of the Janjukian in its broad sense as embracing all phases of sedimentation, of one long time series, the term Barwonian is no longer needed, its members being included in the term Janjukian. The sequence of the beds 1, 2, and 3 as given here has lately been established by the author from evidence obtained in cliff-sections at Muddy Creek near Hamilton, and in the bores put down in the Mallee and at Sorrento.

Other authors since McCoy agreed as to the present sequence, but differed in regard to the age of the oldest beds, which they held to belong to the Eocene, making the succeeding beds correspondingly older.

Guide Fossils.—The various members of the Australian Kainozoic system have been referred by the writer to the horizons given above, chiefly through a study of the Cetacean types, the fish remains, the Mollusca, the Polyzoa, the Ostracoda, and the Foraminifera. In the oldest beds (Balcombian) a predominant fossil is *Amphistegina*, long mistaken for *Nummulites variolaria*, the latter genus in reality being absent. In the limestone phase of the succeeding Janjukian beds the Miocene type of toothed whale, *Parasqualodon*, occasionally occurs; in the marls the Miocene genus *Spirulirostra*; whilst the Burdigalian forms of *Lepidocyclina* are abundant in the polyzoal series of the Janjukian. In the Kalimnan Series, Cetacea, known elsewhere in the Pliocene Crag (Diestian and Astian) of Antwerp and England as *Scaldicetus* and the ziphioid whales, are characteristic fossils. The above interpretation of the Australian Tertiary sediments agrees also with the data acquired by Australian physiographists, and is that generally accepted for New Zealand and Patagonia.

Terrestrial Series.—The terrestrial Tertiary deposits, so far as they are known, are assigned to the various horizons as follows :—

Balcombian.—Leaf-beds of Mornington and the brown coal of the Altona Bay Coal-shaft.

Janjukian.—Leaf-beds of Sentinel Rock (Cape Otway), Haddingley near Bacchus Marsh, Pitfield Plains, Narracan, Dargo High Plains, and the Older Deep Leads: in Victoria. Leaf-beds of Dalton, Gunning, and Vegetable Creek: in New South Wales. Leaf-beds of Lake Frome, etc.: in South Australia.

Kalimnan.—Newer Deep Leads, Haddon, Victoria. Also of Gulgong in New South Wales.

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(2) The Correlation of the Australian Marine Kainozoic Deposits: Evidence of the Echinoids, Bryozoa, and some Vertebrates. By Professor J. W. Gregory, F.R.S.

CORRELATIONS of the Kainozoic deposits which extend along Southern Australia have been proposed in accordance with two main conclusions. According to the first, these deposits include marine representatives of all the Kainozoic systems from the Eocene to the Pleistocene. According to the alternative explanation, most of the deposits belong to the middle part of the Kainozoic, and include essentially one fauna. When I succeeded M'Coy in Melbourne in 1900 I had to consider this question, and carefully examined the evidence given by the two groups of animals in which I was most interested, the Echinoidea and the Bryozoa, and also compared their evidence with that of some fossil vertebrates. The second correlation seemed the better to agree with the evidence of these groups. The Echinoidea had been regarded as indicating the Eocene age of some of the deposits, for one characteristic fossil had been referred to the genus *Holaster*. This determination had, however, been revised and the fossil referred to a new genus, *Duncaniaster*, whose affinities are with much later echinoids than *Holaster*. The fossil echinoids could all be included in one fauna; some of the most characteristic species, such as *Clypeaster gippslandicus* and *Monostychia australis*, range from the Balcombian to the Kalimnan, and *Lovenia forbesi* has the same variations in the Janjukian and Kalimnan. Some of the rarer species are limited to one locality, but that is probably only due to their scarcity. The characteristic Echinoids indicate one fauna, which is essentially Miocene, though it may have overlapped with the Upper Oligocene and Lower Pliocene. The evidence of the Echinoids is decidedly in favour of the view that there has been one great marine transgression along the southern coast of Australia, which reached its maximum in the Miocene if it were not confined to that system.

The evidence of the Bryozoa is less definite, but when carefully examined it supports the same conclusions. Many of the genera lived in the Eocene and Cretaceous; but most weight should be given to the most specialized Cheilostomata found in these deposits. Some well-known living species, such as *Retepora beaniana*, *Smittia reticulata*, and *Porella skenei*, are found in the Victorian beds, and they indicate an Upper instead of a Lower Kainozoic age. The survival of some older Bryozoa is less significant than the first appearance of the highly developed Upper Kainozoic species. Macgillivray in his monograph (1895) said that the Victorian Bryozoan fauna included no Eocene members, and that the different horizons represented were not very different in age. With those conclusions I fully concur.

The vertebrate evidence appears to me to support the same determination. The appearance of *Squalodon*, *Scaldicetus*, and *Ziphius*, and of such well-known species of sharks as *Carcharodon megalodon* and *Oxyrhina hastalis*, which range from the lowest to the highest of the main Victorian marine series, is in favour of those beds being not earlier than Miocene. It is true that both species have been recorded from the Eocene of the United States; but these American Atlantic deposits are not an altogether satisfactory basis for correlation; and these species make their first appearance in the standard Kainozoic succession of Europe in the Miocene, and they last on to the Pliocene.

The classification adopted recently by Mr. Chapman seems to me in essential agreement with the evidence of the Echinoids, Bryozoa, and Vertebrates, most of the marine Kainozoic beds of Southern Australia belonging to the Janjukian and being of Miocene age.

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(3) Discussion on the Age and Sequence of the Victorian Tertiaries. By T. S. Hall, M.A., D.Sc.

THE chief difficulty that meets one in attempting to decide the age of the marine Tertiaries of Southern Australia is their wealth in well-preserved fossils. From the oldest series, the Barwonian, which includes the closely allied Janjukian and Balcombian, about 1,800 species have been described. This includes over 800 Mollusca, some 500 Polyzoa, and about 40 Brachiopoda, 50 Echinoids, 80 Corals, and a large number of Foraminifera. The Kalimnan yields about 260 described species, mainly Mollusca, while the Werrikooian affords close upon 200 species of described Mollusca. It may safely be said that when the fauna of the Barwonian, at any rate, is fully described the total will be doubled, for, taking the Mollusca, the small forms, which are extremely abundant, have not been touched, and a large number of new species in almost all groups are known, but remain undiagnosed.

The basis of classification is in dispute. In spite of all objections I adhere to the Lyellian percentage method as yielding the best results. Another method has been adopted by Ortmann in dealing with the Patagonian Tertiaries. It consists in comparing each species with species of known age in the northern hemisphere, deciding which is the nearest 'ally' or 'representative', and referring the southern formations to those northern ones which yield the greatest number of 'relationships'. It passes by as of no importance all the southern forms. Harris suggests using phylogeny *pari passu* with the Lyellian method.

The objection urged against the Lyellian method is that the personal equation enters too largely into it, and we do not know what a species is. H. von Ihering has discussed Ortmann's method fully, and objects to it. To my mind the personal equation is as prominent in it as in the Lyellian, and it demands an amount of knowledge of the Tertiary faunas of the world that no one can possibly have at first hand, and enormous collections, quantities of each species, that no museum is likely to contain. As regards phylogeny, we cannot use it till we know the sequence.

Confining ourselves to the Mollusca, we find Tate recognizing about a dozen recent species in the Barwonian. Later authors have more or less definitely recognized about half a dozen more. As we have over 800 named species in this series of beds, we may double the number of recent ones without seriously affecting the result.

Assuming that the Barwonian is Eocene, for some age has to be assumed, I have elsewhere discussed most of the genera that transgress.[1] Some pass up from Mesozoic times, others are extensions back from younger horizons in the north, or from recent seas. Besides this the absence of many modern genera must be insisted on. It is customary for those who hold that the Barwonian is younger than Eocene to label all the old genera 'survivals'. This hardly settles the question. Leaving the land fauna on one side, there are some undoubted survivals in the Indo-Pacific, but it may be asked, did nothing originate in the southern seas and slowly migrate northwards? The real place of origin and age of the transgressing genera cannot be settled off-hand by northern standards.

The Barwonian is divided into Balcombian and Janjukian, but their relationship has been vigorously discussed. By far the greater part of the fauna is common to the two. Passing by the discussions between Professor Ralph Tate and Mr. J. Dennant on the one side, and Dr. G. B. Pritchard and myself on the other, which ended, as such discussions frequently do, in a series of flat contradictions as to facts, we may consider Mr. F. Chapman's position.

Mr. Chapman asserts that the Batesford limestone is typical Janjukian, and appears to conclude that all the polyzoal limestones—and there are many—are also Janjukian. He argues on the same data that the Janjukian is the younger series. Tate, Dennant, Pritchard, and myself, however much we differed on other points, agreed that the age of the limestones must be decided by reference to the rich fauna of the clays. Mr. Chapman makes no reference to an intercalated clay bed in the Batesford limestone from which Dr. Pritchard and myself collected forty-five species, mainly mollusca. Of these only one is confined to the type Janjukian locality, while twelve have never been found there, but are confined to typical Balcombian beds. The rest are common to both series. The limestone, then, as we asserted, is Balcombian and not Janjukian. Moreover, we showed, by a careful examination of the area, that the limestone passed under clays which are typically Balcombian, and can be traced to Orphanage Hill, only a couple of miles away. M'Coy grouped the Orphanage Hill beds with those of Mornington, that is, with the type Balcombian section. Tate, Dennant, Pritchard, and myself agree with the grouping, and Mr. Chapman still labels the Orphanage Hill fossils Balcombian in the National Museum. If, as Mr. Chapman asserts, the Batesford limestone is Janjukian, then the Balcombian is

[1] Rep. Aust. Ass. Adv. Science, Hobart, 1902: Pres. Address, Sect. C.

the younger and not the older member, as he asserts. The stratigraphical facts are unimpeachable.

The Mount Gambier limestones must, as the contained Mollusca show, be associated with the Balcombian of Muddy Creek. The polyzoal limestone of Muddy Creek rests on quartz porphyry, and is the basal member of the series. It has been traced by Dr. Pritchard and myself passing under the more loosely compacted beds of the district, and is inseparable from them.

The polyzoal limestones of Jan Juc, Waurn Ponds, and a few other places are Janjukian, and the evidence rests on the Mollusca, but this has no bearing on Mr. Chapman's main contention.

The relative age of the Janjukian and Balcombian is a difficult question. M'Coy, Tate and Dennant, and Chapman consider the Janjukian the younger. Dr. Pritchard and myself consider the reverse to be the case.

As regards the other formations, it may be briefly said that the estimate of their age depends on that of the Barwonian. If this be Eocene, they are Miocene and Pliocene respectively; if not, they must be placed higher in the scale.

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(4) Discussion on the Age and Sequence of the Victorian Tertiaries. By G. B. Pritchard, D.Sc., Lecturer in Geology, Working Men's College, Melbourne.

TERTIARY geology in South-Eastern Australia has been fruitful of much difference of opinion, partly on account of lithological variations associated with palæontological variations which have not always received due weight, the difficulty of correlating disconnected outcrops, bores, and shafts, and the degree of antiquity and relative age of the various horizons represented. The various changes in this work have no doubt been a stimulation to some, but to many it has been, and still is, very confusing.

It happens that marine deposits are well developed, many showing a remarkable wealth of fossils, and these have attracted more attention than their terrestrial and volcanic associates. Amongst the marine fossils, Mollusca are usually very striking, and it is only natural to compare these with Australian living forms. In this way a succession can be determined for the fossil faunas as at present known, showing further and further removes from the living.

1. *Werrikooian.*—The type locality is at Limestone Creek, a small tributary of the Glenelg River, in the parish of Werrikoo, South-Western Victoria. These beds bear a molluscan fauna strictly comparable with living forms along the southern coast except for the occurrence of a few species at present unknown amongst the living fauna.

2. *Kalimnan.*—The type locality is near the township of Kalimna, Gippsland Lakes, Eastern Victoria. The fauna of these beds is also comparable in general facies with the recent, in the proportion of bivalves to univalves, and relative abundance of representatives of other groups. It includes extinct genera, as well as a very high proportion of extinct species.

3. *Balcombian.*—The type locality is at Balcombe's Bay, east shore of Port Philip. The fauna of these beds is richer and more varied than the existing Southern fauna; its general facies is more comparable with Northern Australian forms. In the present state of our knowledge it contains rather more than 2 per cent of extinct genera, and even allowing a wide margin for differences of opinion the living species would barely represent 2 per cent.

4. *Janjukian.*—Coastal sections on Bass Strait, parish of Jan Juc, south of Geelong. The fauna from these beds appears to be furthest removed from the living, based on a review of the genera which shows between 5 and 6 per cent extinct, whilst the species only show about 1 per cent living forms.

When the typical fossils are not obtainable it is not easy to state whether a rock series is Balcombian or Janjukian. To meet this difficulty the wider term Barwonian has been given, as both these horizons are well developed in the Barwon Basin.

Stratigraphical evidence also exists in confirmation of the above sequence in the Moorabool Valley, in the coastal sections from Port Campbell to Cats' Reef and elsewhere.

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(5) The Post-Jurassic Geography of Australia. Notes on the Hypothesis of Isostasy. By E. C. Andrews, Sydney, New South Wales.

The doctrine of isostasy implies the general correspondence, in weight, of all vertical columns of unit size composing the Earth's crust to a depth known as the *depth of compensation.* This depth is taken at 122 kilometres below sea-level by Hayford.[1]

The excess of height of the unit columns, in continental areas, is considered as being compensated by the excess of crustal density in sub-oceanic areas. Isostatic compensation is supposed to follow rapidly upon loading and unloading. Examples of such loading are sedimentation and the formation of a continental ice-sheet, while examples of unloading are erosion and the disappearance of an ice-sheet. The adjustment is considered to be a gradual, rather than a spasmodic, process. Anomalies of gravity, however, are recorded from many localities, and Gilbert[2] suggests that the explanation of such is to be sought in *nucleal heterogeneity.*

Geography.—East and West Australia form two positive, or buoyant, elements, while the Inland Plains, in the main, represent a negative, or sunken, area. With these three elements should be considered New Zealand, Malaysia, the South Pacific, the Indian, and Southern Oceans.

During Cretaceous time a great plain of erosion appears to have been formed in the positive elements of Australia, while the extensive epicontinental sea of that period was filled with the waste derived from the neighbouring erosion. Subsequently, both the old plain of

[1] J. F. Hayford, "Figure of the Earth and Isostasy": U.S. Coast and Geodetic Survey, Washington, 1909.

[2] G. K. Gilbert, "Interpretation of Anomalies of Gravity": U.S. Geological Survey, Washington, 1913.

erosion and the northern portion of the area of sedimentation were elevated to a moderate height and a long period of equilibrium and erosion ensued. This sequence of elevation and of pauses of equilibrium with erosion was repeated until the close of the Kosciusko Period,[1] the pauses between the uplifts becoming less important, but the amount of vertical movement becoming correspondingly emphasized.

At various stages of the process basalts flooded Eastern Australia, especially in areas of older sedimentation. The appearance of the old basalt-covered stream-drifts is suggestive of a temporary subsidence for the plateau areas during the basaltic period.

Strong streams, such as the Shoalhaven and the Hawkesbury, maintained their general courses against the uplifts along their lower portions. Hence it is inferred that the uplifts were effected slowly; nevertheless, the periods of equilibrium separating the revivals of elevation were of much longer duration than the uplifts themselves.

The researches of Dutton, Hayford, Bowie, Gilbert, and others appear to have placed the doctrine of isostatic compensation upon a firm basis; nevertheless, the operation of the adjustments does not appear, as yet, to be understood, and it is probable that cognizance has not been taken of all the factors.

In the example cited, of the elevation of both the great Mesozoic peneplain and a great portion of the loaded offshore area, it seems difficult, under the doctrine of continuous compensation, by erosion and sedimentation, to explain, in the first place, how the positive element could remain, for ages, in the one general position of equilibrium, while the offshore area was being loaded; and, in the second place, how the elevatory movement could have received its initial impetus, especially as the effect appears greater than the cause if it be assumed that the Cretaceous sedimentation gave rise to the Tertiary uplifts. On the other hand, the foundering of sub-oceanic areas in the neighbourhood might be adduced as an explanation, but the evidence is not at all conclusive on this point.

The history of the revivals of elevation during Tertiary time over Eastern Australia indicates crustal adjustment by jumps, and in this case also the increasing amount of vertical movement suggests that the elevations of the plateaus more than compensate for the erosion sustained in these regions during recent geological time.

The extrusion of basalts is in harmony with the doctrine, but the action appears to have been catastrophic rather than gradual in nature.

The sequence of geographical forms cited suggests that sedimentation influenced the formation of plateaus only in a minor degree, but, on the other hand, that stresses accumulated gradually within the zone of compensation, until a belt of weakness, or mobility, was established by means of which the ill-adjusted portions were connected. Upon the arrival of such a stage adjustment ensued with relative rapidity with the production of epeirogenic uplifts and depressions. This neither denies the ability of a load, such as a mass of sediments, or an ice-cap, to depress the underlying region, nor does it seek to exclude

[1] Closing Tertiary.

the tendency for an unloaded area to rise; it merely assigns to such agents a subordinate part in the shaping of the greater features of the Earth's crust.

It is probable also that an analysis of a series of gravity measurements which may be taken hereafter in Australasia would reveal the existence therein of gravity anomalies, and it is probable also that the disposition of these would be other than those which might have been inferred from a mere inspection of the topography.

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(6) GEOLOGY OF RAMSEY ISLAND, PEMBROKESHIRE. Final Report of the Committee, consisting of Dr. A. STRAHAN (Chairman), Dr. HERBERT H. THOMAS (Secretary), Mr. E. E. L. DIXON, Dr. J. W. EVANS, Mr. J. F. N. GREEN, and Professor O. T. JONES.

THE Committee have to report that the grant made to them in 1913 to aid Mr. J. Pringle in continuing his researches in the west of Pembrokeshire has been spent. They have also to report that the detailed mapping of the island has been completed. The examination of the rocks and fossils which have been collected will be proceeded with.

For the purpose of description the island can be divided conveniently into two areas—a northern area composed of Lingula Flags, Arenig Mudstones and Shales, Lower Llanvirn, and the intrusive mass of Carn Ysgubor; and a southern area of Lower Llanvirn Shales with interbedded tuffs and rhyolites, and a thick mass of intrusive quartz-porphyry. To the latter area belongs the mass of rhyolitic and brecciated tuffs of Carn Llundain.

NORTHERN AREA.

Lingula Flags.—The Lingula Flags consist of bluish-grey, flaggy, micaceous shales with ribs of hard grey close-grained sandstone, some of which reach a thickness of 2 feet. They occupy the headland of Trwyn Drain-du, and they extend eastwards to Bay Ogof Hên, while on the eastern side of the island they form the cliffs from the north-east corner to Road Uchaf. The Flags also occur in the headland to the south of Abermawr. They are highly fossiliferous, and yield *Lingulella davisi* in great abundance.

Arenig.—All the zones of the Arenig are present. The lowest beds are bluish-grey sandy mudstones and shales with *Ogygia selwyni*, *Orthis proava*, and *O. menapiæ*. They are confined to the north-east corner of the island, and are faulted against the Lingula Flags. The mudstones are followed by bluish-black shales belonging to the Extensus zone, and are well displayed in the cliffs at Road Uchaf and Road Isaf. Similar shales belonging to the Hirundo zone are present in Abermawr.

Lower Llanvirn.—The base of the Lower Llanvirn is seen only in the cliffs in Abermawr, where the shales of the Hirundo zone are succeeded by a thick series of hard dark and light-coloured tuffs of fine texture, which yield *Didymograptus bifidus* in their highest beds. The tuffs are followed by fossiliferous blue-black shales, but their full thickness is not seen in the northern area.

Intrusive Rocks.—Carn Ysgubor is formed of an intrusive mass of quartz-albite-diabase, which has invaded the sediments of Lower Llanvirn, Arenig, and Lingula Flags. A small intrusion occurs south of Abermawr, where Lingula Flags are in contact with a quartz-keratophyre.

Southern Area.

This area was described in the first report, in which it was shown to be composed of *D. bifidus* shales which had been invaded by a thick mass of quartz-porphyry. The shales, well displayed in the cliffs of Porth Llauog and Foel Fawr, are highly fossiliferous, and a large collection of graptolites has been made from them. They contain layers of coarse agglomeratic tuff, and at Foel Fawr pass upwards into thick beds of tuff which are conformably overlain by grey rhyolites. The tuffs and conglomerate on Carn Llundain belong to the same period of eruption.

The two points of interest, therefore, which were made the object of mapping the island have been successfully solved. It has been found that the so-called Tremadoc Beds are Arenig sediments, and that they do not pass downwards into the Lingula Flags, but are brought against them by a fault; also that the rocks hitherto regarded as pre-Cambrian belong to a period of igneous activity that occurred in Lower Llanvirn, or even later, times.

It is hoped that the full description of the district will be completed this year, and it is the present intention of Mr. J. Pringle to communicate the results of his investigations to the Geological Society of London.

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(7) Structural Features of the Coal-fields of Pennsylvania and their Influence on the Origin of Hard Coal. By Professor E. S. Moore, M.A., Ph.D.

THERE are two main coal-fields in Pennsylvania, the Bituminous and the Anthracite. The latter field comprises an area of approximately 480 square miles situated in the highly folded portion of the Appalachian Province, while the former field covers a much larger area with but gently folded strata. Between these two fields are limited areas underlain by semi-anthracite coal in strata which have suffered a medium amount of diastrophism.

So close is the relationship between intense diastrophism and the development of anthracite coal, that the influence of pressure—combined with conditions favourable for the escape of the volatile constituents from the vegetable matter—seems to be self-evident, although other theories, such as the action of bacteria, etc., have been advanced to account for the origin of anthracite. The structure of some of the anthracite basins is extremely complex, and the coal can often be mined only by special methods, especially where the Mammoth seam reaches 60 feet in thickness.

In the Bituminous field, 'rolls' and 'horsebacks' are common, and investigation has shown that these, usually, nearly parallel the larger mountain structures.

REVIEWS.

I.—The Quaternary Ice Age. By W. B. Wright, of the Geological Survey of Ireland. pp. xxiv + 464, with 23 plates and 155 text-illustrations. London: Macmillan, 1914. Price 17*s*.

THE literature of glacial geology, both European and American, has of late years attained enormous proportions, and much of it is very inaccessible. The author has set himself the task of giving a summary of the latest conclusions in this interesting field, and it must be said that in this he has admirably succeeded. The book is evidently the result of a vast amount of reading, much of which must have been of monumental dullness, and the author's intimate acquaintance in the field with the Quaternary geology of the British Isles adds very greatly to its value and interest.

The whole forms an admirable summary of modernist views of glaciation and of the general geology of the Quaternary period in Britain, Scandinavia, the Alps, and North America, and the latest results of prehistoric archæology are freely utilized. It is becoming abundantly clear that in the study of human remains lies the best chance of solving the problem of the correlation of the British drifts with those of other areas, especially with regard to the occurrence of interglacial periods in this country.

To the majority of readers the most interesting portion of the book will be that dealing with the glaciation of Great Britain and especially of eastern England, as to which there is still much controversy. The author has here contented himself with an exposition of the land-ice theory in its most complete form. It should, however, have been made clear that the land-ice theory is not proven. The mechanical difficulties involved are very great. Even on the most favourable assumptions the possible angle of slope of the ice from the Scandinavian centre of glaciation to the Yorkshire coast is under 1°, and it is difficult to see how such an angle of inclination could produce sufficient driving force to bring about the tremendous effects postulated by the Yorkshire school of glacialists. Many of these difficulties have been effectively stated by Professor Bonney in his presidential address to the British Association at Sheffield. On this subject it is at any rate necessary to preserve an open mind, since with our present knowledge the problem seems to be insoluble. At any rate it is scarcely sufficient to dismiss the "Great Submergence" in four lines as a "geological fiction", as is done by the author.

Special attention is paid to the connexion between raised beaches and glaciation, and here comes the most original part of the book. According to the theory suggested the variations in the relative levels of land and sea are due to a combination of two causes: firstly, the actual lowering of the sea-level owing to accumulation of water on land in the form of snow and ice, and secondly, a slow isostatic rise of the land after removal of the heavy ice-cap which had previously led to depression of the region. This theory is worked out in a very convincing way with reference to the raised beaches of Scotland and the known variations of the Baltic which have been so ably studied by the Scandinavian geologists. It is argued that the pre-glacial sea-level was much the same as at present. By this is presumably meant the immediately pre-glacial level, since the Pliocene plateau of southern Britain certainly indicates a much lower position of the land at that time. More attention might perhaps have been paid to the relation of the raised beaches of the south of England and of South Wales to the 'head' and other somewhat mysterious deposits that have been claimed as of glacial origin, since these seem likely to throw light both on interglacial periods and on the arrival of man in this country.

The general get-up of the book and the illustrations are excellent; it is perhaps permissible, however, to register a gentle protest against its inordinate weight.

R. H. R.

II.—Cambridge Manuals.

Coal Mining. By T. C. Cantrill, B.Sc., F.G.S. pp. 159. Cambridge University Press, 1914. 1*s.* net in cloth, 2*s.* 6*d.* net in leather.

This little volume forms an interesting addition to a well-known series. The author's aim has been to give a general sketch of the history and principles of coal-mining, and he has been quite successful.

In the introduction it is pointed out how intimately our whole civilization is bound up with this industry, and the history of the use of coal is traced from the earliest record, about 300 B.C., to the present day. Incidentally we are given an account of the evolution of the steam-engine in connexion with pumping and haulage.

We are next introduced to the various kinds of coal and their several uses, the geological conditions of its occurrence, and the use of fossils in distinguishing one part of the Coal-measure Series from another.

The value of a geological survey and the methods of prospecting and boring are discussed, also the difficulties which are encountered in the process of winning the coal, such as the accumulation of water or gas and the presence of faults and washouts. A good idea is given of the principal methods of working, ventilating, draining, and lighting the mine and of underground haulage.

Finally legal and administrative matters are dealt with. The book, although a mere sketch of the subject, has the outlines well arranged and is written in an interesting style, which holds the attention of the reader throughout.

III.—Canada Department of Mines. Geological Survey: Museum Bulletin No. 2. 8vo; pp. iv + 140 (of which 4 are printed as plates), 4 folding tables. Ottawa, July 30, 1914.

The first number of this publication was entitled "Victoria Memorial Museum Bulletin No. 1", and was reviewed in the Geological Magazine for February, 1914 (p. 88). We then said that if it were "intended for the prompt publication of short papers it might prove very useful". It may be that this is the intention, but we would deprecate any illusory appearance of promptitude such as is conveyed by the dates June 5, 17, 19, 22, July 3, 6, and 11, placed at the head of the respective articles, as though they had been published on those dates. We have no reason to suppose that such was the case, and indeed the fact that no copies were received over here before the second week in October leads us to regard even the alleged date of the whole number with some suspicion.

Mr. S. J. Schofield discusses the origin of the micro-pegmatite in the sills that traverse the Precambrian Purcell Series of British Columbia, and concludes that the rock was derived from the upper more acid stratum of a magma in an intercrustal reservoir, while the lower more basic strata gave rise to gabbro sills. Mr. Schofield also writes on the Precambrian (Beltian) rocks of South-Eastern British Columbia, and gives a new correlation table.

Dr. E. M. Kindle describes columnar structure in a bed of Silurian limestone in Eastern Quebec, and regards it as due to sun-cracks during deposition.

Mr. J. W. Goldthwait discusses and rejects various supposed evidences of subsidence of the coast of New Brunswick within modern time.

Mr. L. D. Burling contributes a paper on "Early Cambrian Stratigraphy in the North American Cordillera, with discussion of Albertella and related faunas", which he believes to occupy strata transitional between the Lower Cambrian sandstone and the Middle Cambrian limestone, and to be more related to Middle than to Lower Cambrian.

Miss Alice E. Wilson has studied the plications of the brachiopod shell *Parastrophia hemiplicata*, which show great variation. It appears that the plications came in gradually, following the natural process of individual growth, with gradual acceleration of development as geological time progressed. Palæontologists always seem to find that the transmutation of species has taken place in this way. Modern geneticists try to force another interpretation on the facts, but the process requires marvellous ingenuity.

F. A. B.

IV.—The Australian Tertiaries.[1]

ONE of the most interesting problems discussed at the British Association's meeting in Australia was the age of the Australian Tertiaries. Mr. Frederick Chapman, who brought to bear upon the question his wide palæontological knowledge, prepared and issued in July last as No. 5 of the Memoirs of the National Museum of Melbourne a paper "On the Succession and Homotaxial Relationship of the Australian Cainozoic System". After discussing the time equivalents, the relative value of the percentage method, comparison of typical faunas, widely distributed fossil types and their significance, he proceeds to dissect the evidence of the Foraminifera. Having shown that the so-called Nummulines are true Amphistegines, he

[1] See Notices, *ante*, p. 514.

writes a conclusive chapter on the complex-structured Foraminifera in the Australian Tertiary System, and fairly shows that the oldest Tertiary beds of the Australian Series can be no older than Oligocene, and that the Eocene formations are not represented in the continent as at present known. So far as the author can judge he correlates the Australian beds with the European equivalents as follows:—

Kalimnan = Pliocene (Lower).
Janjukian = Miocene: Aquitanian to Tortonian.
Balcombian = Oligocene: Priabonian to Rupelian.

Mr. R. B. Newton, who was present at the meeting, allows us to say that in his opinion Mr. Chapman's conclusions are substantially correct, the evidence of the Foraminifera being of especial value and importance in Tertiary times, while the Molluscan evidence strongly supports the Foraminiferal.

The stratigraphical notes bearing on the sequence of the strata are put together in a masterly fashion, will be of great value to workers both in and out of Australia, and will, we believe, add considerably to Mr. Chapman's reputation.

V.—Our Eastern Coal-field.

Dr. NEWELL ARBER'S long-awaited paper on the Geology of the Kent Coal-field has now appeared in the Transactions of the Institute of Mining Engineers, xlvii (5), 1914, pp. 677–724. After a brief historical sketch the author gives the evidence which he has utilized consisting of an account of the various borings. He then discusses the form of the basin and its boundaries, the dip and strike of the beds and the faulting, with the contours of the Palæozoic floor. The age of the Carboniferous rocks met with, their lithology, types of coals, and flora and fauna occupy another section, and the paper ends with conclusions, summary, and bibliography. From the summary we learn that the field has an acreage of 128,000, of which a large portion lies under the sea. The general strike is 30° S. of E. and N. of W. and the dip (in the only two places where available) is 2 to 3. The area is a syncline occupying an anticline with folds of an Armorican trend. The northern boundary seems for the most part south of the northern coast-line of Kent. Upper and Lower Carboniferous beds are present, the latter exceeding 450 feet in thickness with surface denuded before the deposition of the Upper Series. The Coal-measures themselves consist of the Transition (1,700–2,000 feet) and the Middle (2,000 feet), the Lower with the Millstone Grit being unrepresented. They are grey; no red beds, Espley rocks, nor *Spirorbis* limestones occur. Igneous rocks have not been proved, and ironstones and limestones are either absent or very rare. The coals are well distributed, often of considerable thickness and value, but have a tendency to split. Altogether a highly valuable contribution to the geology of the South-East of England.

CORRESPONDENCE.

ORIGIN OF THE IGNEOUS ROCKS.

Sir,—I was much interested to read in your last issue the excellent review of Professor's Daly's latest work appearing above the initials "R. H. R." May I draw your reviewer's attention to the fact that such points as the quantitative composition of the igneous rocks and the effects of assimilation upon them have been dealt with at some length in England before now, as your own pages can testify. In this Magazine as long ago as June, 1904, I entered a protest against the calculations made on a purely arm-chair basis by F. W. Clarke and A. Harker with regard to the former problem, and Mr. Clarke has, to some extent, modified his calculations as a result of this and a succeeding paper on the same subject. With regard to assimilation, a process intimately connected with the question of composition, Professor Grenville Cole has been crying in the wilderness for many years past, and the late Dr. Johnston-Lavis has done good work in the same direction, while I attacked the problem on a much wider basis in a lengthy paper read before the British Association in 1905. This has been followed up by a general work on petrology, of which an expanded form was published by Messrs. Chapman & Hall last year. In substance it is a systematic exposition of the subject based on assimilation as opposed to the purely hypothetical 'differentiation' basis which has become so popular of late years. It may, perhaps, be added that Professor Daly has placed a great stumbling-block before many geologists by his advocacy of a prevailing basic magma, below the granitic one, as a primary feature of his work.

49 London Wall, E.C., *Oct. 6, 1914.* F. P. Mennell.

THE OLD OR GREY GRANITE OF THE TRANSVAAL AND ORANGE RIVER COLONY.

Sir,—On May 13 of this year a paper was read in the Geological Society of London by F. W. Penny, B.Sc., F.G.S., "On the Relationship of the Vredefort Granite to the Witwatersrand System" (see Geol. Mag., July, 1914, pp. 332–3), wherein the writer suggests "that the Vredefort Granite, instead of being 'Archæan', is of a post-Pretoria–pre-Karroo age, if not contemporaneous with, at least connected with, the same epoch of igneous activity as the 'Red Granite' of the Northern Transvaal".

Thus nearly six years after the publication of my paper on "The Age of the 'Old or Grey Granite' of the Transvaal and Orange River Colony" in the Geol. Mag., Dec. V, Vol. V, No. 534, pp. 552–9, another serious investigator arrives at the identical conclusion, evidently quite independently, as Mr. Penny, although quoting various authors, seems to have been quite unaware of the existence of my paper above mentioned.

I still hold the firm conviction that the adoption of the above detailed conclusion, although revolutionizing to a large extent all that has hitherto been accepted, will prove the only way to place South African geology on a sound and true foundation.

Haarlem, Holland, *Sept. 21, 1914.* C. G. S. Sandberg.

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No. XII.—DECEMBER, 1914.

ORIGINAL ARTICLES.

I.—The Lateritic Deposits of Mozambique.

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

(PLATE XXXVII.)

IN his *Last Journals*, referring to the formations of Portuguese Nyasaland west of the Lugenda River, Livingstone writes: "The elevated plains among these mountain masses show great patches of ferruginous conglomerate, which, when broken, looks like yellow hæmatite with madrepore holes in it." He also notes that the same formation is responsible for the prevailing reddish tint assumed by the soil. In Mozambique, the province of Portuguese East Africa south of Nyasaland, lateritic deposits of the kind described by Livingstone are very abundant. In view of the wide interest which the superficial deposits known as laterite have aroused among geologists during recent years, no excuse seems necessary for placing on record a few notes dealing with their modes of occurrence and associations in Mozambique.[1] The country was explored during the year 1911, Mr. D. A. Wray, Mr. E. J. Wayland, and myself accompanying the expedition as geologists. My former colleagues have kindly placed their notes on the superficial deposits of Mozambique at my disposal, and I wish here to express my indebtedness to them for the help thus afforded.

Following the nomenclature of Dr. L. L. Fermor,[2] the lateritic deposits of Mozambique may be classified as laterite, quartzose laterite, and lateritic sand or earth. Cases of the occurrence of lateritoid, formed by the metasomatic replacement of the underlying rocks at their outcrops, are doubtful, and, in any case, are of little importance compared with the widespread occurrences of other types, the chief of which is quartzose laterite. The latter forms exceedingly hard, slag-like masses, brown and varnished at the surface, but paler in colour where unexposed to the atmosphere, as, for example, on freshly broken surfaces. The rock is frequently concretionary and cavernous, the holes being occupied by a powdery ferruginous earth, or by angular and subangular fragments of quartz, which with fragments of other

[1] For a short account of the geology and geography of Mozambique see respectively Holmes & Wray, Geol. Mag., 1912, p. 416, and Holmes & Wray, *Geog. Journ.*, xlii, p. 143, 1913. For a map of Mozambique, prepared from the results of the expedition of which the present writer was a member, see *Geog. Journ.*, xlii, p. 112, 1913.

[2] Geol. Mag., 1911, p. 514.

minerals and rocks, less commonly found, sometimes makes up a considerable proportion of the formation. Many of the laterites are richly ferruginous, and comparatively poor in aluminium hydroxides.[1] On the other hand, examples of nearly pure bauxite are known, and between the richly ferruginous and richly aluminous varieties intermediate types occur. Oxides of manganese and titanium are also present, sometimes considerable quantities of the former constituent. Only qualitative analyses of specimens examined in the field and of those brought home have so far been made, so that it is not possible to give more than the above general indication of their composition.

The rocks over which laterite occurs in Mozambique are of various kinds. Mr. Wray records its presence in numerous instances on hornblende gneiss (e.g. north of Namkoko) and on biotite gneiss (e.g. between Mkonta and Ntia). Mr. Wayland found it on different varieties of gneiss and on basalt. The sedimentary belt (Cretaceous and Tertiary) of the coast is free from laterite, which, however, is of frequent occurrence on the basalts of the Tertiary volcanic belt. Although detrital quartz is here still the commonest inclusion, occasionally fragments of agate or of basalt may be found. Indeed, the former distribution of the basaltic flows may to some extent be inferred from the presence of fragments of basalt in laterite where no basalt now exists in situ. On the metamorphic plateau beyond the coastal belt, it is worthy of notice that no ferruginous laterite was ever found on granite. The Mozambique granites are uniformly poor in ferromagnesian minerals, whereas the gneisses, which are very abundant and are the most usual hosts of the laterite, are generally rich in dark bands of hornblende and biotite. On the Mluli River, just north of the Mwipwi Mountains, laterite occurs on a gabbro rich in labradorite and impregnated with pyrite. It occurs on a similar rock on the eastern side of the Lulaua River near its confluence with the Ligonia. Near the Erikola Peaks I found laterite on a hypersthene-plagioclase dyke rock which also contained pyrite. The ubiquitous gneiss of Mozambique is penetrated by numerous pegmatite veins which are frequently rich in magnetite and hæmatite, especially in the western parts of the territory. They are generally parallel to the strike of the banding and foliation of the gneiss, although they may also be transverse, sometimes forming a complicated network. Although the average width of the veins amounts to only a few inches, crystals of iron-ore as large as a walnut are not uncommon. South-west of the Ribawe Mountains the superficial rock debris is rich in hæmatite, a mineral greatly prized by the natives, who collect it for the manufacture of spear-heads and knives. The importance of such iron-bearing rocks in the genesis of ferruginous laterite is obvious.

In some cases the laterite was found to lie on unaltered fresh rock, a conclusion which microscopic investigation has since supported. However, the underlying rocks were always moist and frequently they were soft and disintegrated, limonite having been deposited between the mineral grains. Pits sunk in the lateritic earths showed that these lay on a floor of soft moist gneiss, with large and small

[1] By many geologists some of these deposits would be referred to as lateritic iron-ores.

fragments of iron-stained gneiss in the lower layers of the deposit. The general upward succession appears to be from unaltered gneiss through moist disintegrated gneiss to similar material deeply stained with a ferruginous cement. On this lay the lateritic earths, damp in their lower levels, but dry above, and with a strong concentration of the lateritic constituents at or near the surface.

The laterite shows a striking disposition to lie in well-marked bands, sometimes continuous but generally broken, parallel to the strike of the underlying gneiss, or to the pegmatite veins which penetrate the gneiss. It is found only on the gently undulating plateau and never on the steep slopes or summits of the inselberg peaks and mountain blocks which, as one proceeds westwards from the coast, rise up abruptly in increasing numbers and altitude. The plateau surface itself, which rises from sea-level at the coast to a height of 1,000 feet at Nampula, to nearly 2,000 feet around the Ribawe Mountains, and to about 3,000 feet in the neighbourhood of the Namuli Peaks, is diversified by numerous low ridges traversing the country parallel to the strike of the gneissic foliation, the direction of which lies between N.E. to S.W., and N.N.E. to S.S.W. (Fig. 1). These ridges have a 'dip' slope which usually lies on the west or north-west side, and an 'escarpment' slope, the gradient of

FIG. 1.—Typical Section in Maravi's country, north of the Mitikiti River, illustrating the occurrence of laterite on the escarpment slope of a ridge.

which, however, is only a little steeper than that of the dip slope. The prevailing dip of the foliation and banding, especially in the eastern part of the country, is in a direction away from the sea, so that when the angle of dip is low, the truncated foliation of the gneiss is more plainly visible on the escarpment slope than on the dip slope, wherever an exposure is encountered. The first and simplest feature in the distribution of laterite in Mozambique is that it frequently lies in bands near the crests of the ridges on the escarpment side (Fig. 1). It thus comes in many places to have the appearance of being actually interbedded with the gneiss. Mr. Wray records a good example which he found between the Mrupi Mountains and the Luli River. There he traced an important band, continuous for a mile and a half, between two hard outcropping bands of coarse hornblende gneiss.

Bands of laterite are also commonly found near the sides of small watercourses, the majority of which dry up during several months of the year. Mr. Wayland was impressed with the fact that many of the bands lie on the eastward side of the gullies, and that where laterite is found on both sides the development is greater on the eastward side. My own field maps indicate several such occurrences which are, I think, to be correlated with the predominant direction of dip of the foliation of the gneiss, for in such cases the dip is generally down towards the streams on the eastward side, and away from them on the westward side (Fig. 2). Instances could also be given (e.g. south of Otetani, by the Monapo River) where the dip is towards the streams from the westward side and where the laterite is restricted to the westward side. In other cases no such correlation is possible, laterite being equally developed on both sides, as for example along the upper course of the Namieta River, which cuts transversely across the gneiss.

In the western part of the territory, where the mountain blocks are more numerous and lofty, where the dip is more frequently at a high angle, and where the streams are less liable to become completely dry during the rainless season, laterite tends to occur in widespread sheets as well as in individual bands. In the sheets themselves, however, a broadly banded structure may often be discerned, strong, hard,

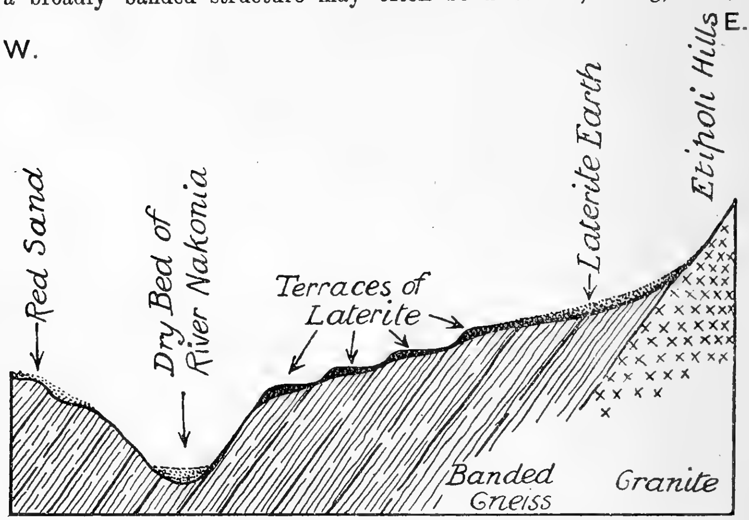


FIG. 2.—Section at the foot of the Etipoli Hills near the Ligonia River, illustrating the occurrence of laterite on the eastern side of a gully.

quartzose laterite alternating with what is little more than a lateritic earth capped with a hardened ferruginous cement. Such sheets are common between the Chica Range and the Ligonia River, in the district south of the Ribawe Mountains, and between the Mluli Mountains and the Luli River. In thickness the lateritic deposits are very irregular, varying within a short distance from a few inches to several feet.

The relation of laterite to vegetation has been the subject of very diverse opinions. In Mozambique it was evident that where the forest and undergrowth were thick no laterite occurred at the surface. In fact, the deposit was almost always associated with areas where the superficial debris was clean and free from organic matter and the so-called 'humus' acids. It has been asserted that the humus acids can decompose silicates, but since the humus acids are themselves insoluble in water alone, their efficiency in the production of laterite is doubtful.[1] Alkaline solutions readily dissolve the humus acids, and it therefore appears that where dissolved silica is found in association with the latter the alkalis have been the effective solvent of the silica.

Laterite was never observed in the neighbourhood of marshy land or swamps, which appeared always to be comparatively free from ferruginous deposits of any kind.

In view of the evident importance of underground drainage in the genesis of laterite, it may be of interest to describe a cave deposit which was examined by Mr. Wayland and myself. Our first base camp was built at Sawa, on a projecting spur in a deep valley running northwards into the Ribawe Mountains. On each side of the valley the mountains rose up precipitously, and the foliation of the gneiss could be plainly seen dipping away at a gentle angle to the north (Plate XXXVII). On the eastern side the nearly vertical face of the gneiss was eaten away here and there into caves, the entrances to which ran along the 'dip'. Those which we explored widened and narrowed in the most remarkable way, defying explanation. In each case a steady drip of water trickled from the roof and from narrow fissures which penetrated the rock parallel to the foliation, thus demonstrating that a considerable drainage of water percolated northwards down the 'dip' through the apparently impermeable gneiss. The roofs of the caves were lined with a thick highly polished deposit of limonite which also covered the upper parts of the walls, gradually becoming thinner as the floor was reached and giving place to bright pink rhodochrosite and black pyrolusite. Where a true floor was visible it was also covered with these minerals, the manganese oxide and carbonate coating the thicker deposits of limonite. In the largest cave, however, much of the floor was buried under the droppings of bats, and this was encrusted with fine needles of vivianite. We had a hole dug through this material in order to expose the gneiss below, and were astonished to find a considerable thickness of sand, in which, at a depth of about a foot, we found the ashes of a wood fire and fragments of coarse pottery, proving a former human occupation of the cave and suggesting that, at least in part, its excavation may have been due to human agencies. The gneiss itself, when uncovered, was found to be perfectly fresh.

The source of the deposits was not difficult to find, for the hill is penetrated with numerous pegmatite veins rich in magnetite and franklinite. Water, charged with carbon dioxide, would readily leach out iron and manganese as carbonates. On reaching a cave, oxidation and evaporation would cause a precipitation of iron-hydroxide, followed by that of the more stable manganese carbonate, some of which would slowly become oxidized to pyrolusite.

This example has been described in order to demonstrate the percolation of iron-bearing solutions along the fissures and foliation planes of gneiss, a phenomenon which appears to be responsible for much of the laterite of Mozambique. Similar cave deposits have been recorded from Mt. Tugwi, near Nampula. On the western side of

[1] Clarke, *Data of Geochemistry* (U.S.G.S. Bull. 491, p. 98, 1911).

a hill near Nakavala, known as Mhala, a cave has been formed by the breaking away of a large mass of gneiss, clearly due to slipping along a moistened joint plane parallel to the foliation, which here dips steeply towards the west. Here also, three or four hundred feet above the plateau, a slow trickle of water percolated through the hill, but only a very thin coating of limonite had been deposited on the roof, and practically none on the steeply sloping floor. In this case the gneiss was free from impregnations of iron-ore. Near the Portuguese fort at Chinga, a spring of iron-bearing water strongly charged with carbon dioxide rises through the gneiss and forms the source of a stream which flows during the dry season to the dried-up channel of the Namieta. On each side of the stream and around Chinga itself are considerable spreads of laterite and lateritic earths.

It is important to notice that the steep slopes of the inselberg peaks and mountain blocks are always free from deposits of the lateritic constituents. Solutions must certainly exist which on evaporation would give rise to such deposits, but the mountain rains and night dews suffice to carry them down to the debris-covered plateau surface below, where they contribute to the formation of the lateritic earths which so frequently sweep round the base of the hills.

The close association of bands of laterite with watercourses has already been mentioned. It is therefore significant that the lower parts of large river beds (e.g. the Monapo), which in the dry season shrink to a succession of stagnant pools, often contain a considerable number of tiny ferruginous nodules distributed among the gneissic and granitic debris of the river floor. In small tributary streams which dry up completely, nodules which reach the size of a small bean are frequently very plentiful, and in some cases the beds are locally paved with sandy laterite, formed by the cementation of large numbers of the nodules with gravel and sand. One of the best examples occurs in a gully which drains into the Nrassi River from the high peak of Ericola. Here many of the nodules were found to have a nucleus of sand. This district was carefully studied by Mr. Wayland, and independently by myself, and we found that the gully did not pass through any lateritic deposits, so that the nodules were not detrital but were clearly formed *ab initio* in the dried-up bed. Mr. Wray found a lateritic conglomerate on the floor of a dry stream near Ribawe, between the Sawa and Ntumba Valleys, where it rested directly on a coarse gneiss. In the dry streams of the Nrassi district every gradation can be found between tiny nodules of iron-ore and massive nodular conglomerate which often is developed on the up-stream side of large boulders and ridges, owing to the accumulation of large numbers of nodules and their subsequent cementation. In the beds of streams which do not dry up, such as the Sawa, the Bwibwi, and other streams in the mountainous areas, no nodules could be found amongst the gneissic gravel. This clearly proves that the nodules are formed only where there is an alternation of saturation and solution, with evaporation and precipitation, corresponding to the 'wet' and 'dry' seasons respectively. The ground water below the *thalweg* dissolves the lateritic constituents from the underlying rocks, and as the stream dries up some of this water rises to the surface by capillarity and evaporation. The solutions are strengthened both by adsorption in the interstices of the sand and by contact with a previous precipitation. For this reason a nodule once begun tends to continue growing, for at its surface the concentration of the solutions is strongest and precipitation by oxidation is therefore more favoured than elsewhere. In this connexion it is interesting to notice that the sands and gravels of dry streams are not strongly iron-stained, except where a hard floor of laterite has formed, the iron being almost entirely concentrated in the nodules. The smooth, rounded, and frequently spherical forms of the latter are due to the fact that deposition is most favoured where the radius of curvature is greatest.

Having now demonstrated the existence of waters, bearing in solution the lateritic constituents, and draining along the foliation planes of the gneiss, and having also shown that these constituents are deposited where evaporation and oxidation can occur, it is possible to turn to the laterite proper and attempt an explanation of its formation. Near the eastern banks of streams where the gradient has cut across the foliation of the gneiss, ground water from the *thalweg* is drawn up by capillary attraction and evaporation, and at or near the surface, where the solutions become oxidized, deposition takes place. It is possible that this action is strongest immediately after the wet season, when the laterite itself is soaked, and deposition is most vigorous at the upper surface. In this way the formation gradually grows upwards as a mechanical replacement, incorporating rock debris (generally quartz and sand) which has fallen upon its surface. Later in the dry season, as the level of the ground water sinks, deposition will occur at lower and lower levels, a possibility which is in keeping with the fact that the Mozambique laterite becomes less and less cavernous with depth. On the other hand, the lateritic earths which envelop the base of the mountains are always damp, fed daily by the heavy dews which are precipitated on the steep rocky slopes, and here a thin hard capping of laterite is found only at the surface, the deposition falling off rapidly in depth owing to the prevalence of permanent moisture. The explanation offered above for the formation of laterite on the sides of streams serves equally well for its occurrence on the sides of ridges where the foliation is truncated by the slope of the land, for fissures are more abundant parallel to the foliation than across it and the upward drainage takes place more easily along the foliation than across it.

The simple cases so far considered do not, of course, include all the occurrences of laterite in Mozambique. Bands of laterite are occasionally found running across the strike of the gneissic foliation, and in so far as such cases are rare it is possible that the circumstances attending their formation are also somewhat special. Pegmatite dykes and joints may also be found running transversely to the main structural lines, and it is obvious for these and other reasons that the underground drainage is not solely conditioned by the foliation. If, however, the more general statement be made that the formation of laterite depends on the drainage and evaporation of the ground waters, I believe most of the Mozambique examples would be included.

It has already been stated that ferruginous laterite was not found on granite. The occurrence of aluminous laterite or bauxite on granite has, however, been observed. Mr. Wayland found a reddish iron-stained bauxite on pyrite bearing pegmatite veins running through the gneiss near the Nrassi River due east of Erikola. Later I found similar material over a small granite intrusion which was plainly visible in a gully draining the southern slopes of Erikola to the Nrassi. Mr. Barton, the leader of the expedition of which we were members, found at Nakota, north of the Ligonia River, large pegmatites mineralized with sulphides. Some of these were capped with bauxite, and, equally interesting, the gneiss in the neighbourhood was for a considerable depth metasomatically replaced by silica. This association would appear to be genetic, but as I was ill with fever at the time and camping at Akwari, several miles away, I was unable to study the deposits myself and cannot therefore discuss them further.

It only remains to place on record the occurrence of kaolin as an alteration product of granite. This was found by Mr. Wayland near the Chika Range, and by myself on the side of a deep gully north of the Mwipwi Mountains and west of Arunto. In the latter case the granite is reduced to a china clay rock in all respects similar to that of the Cornish granites. It was well exposed in section, as the Portuguese had made a small quarry in order to pave with the soft china clay a wooden bridge which carried the military road over the gully. Traced to the north and east, the kaolinized granite gradually gives place to fresh unaltered granite as seen where it outcrops. Where the kaolin occurs, however, there was no natural outcrop, for above the rock a thick deposit of black damp soil, rich in organic material, hid it from view. The vegetation on each side of the gully was unusually thick. It is possible that the kaolin may have been derived from felspars by the action of organic acids or of carbonated waters produced by them. Similar cases have previously been described.[1]

There are, then, in Mozambique, precisely similar granites, in some of which the felspars have broken down into kaolin, while in others aluminium hydroxides have been formed, combined silica having been liberated and removed, or redeposited metasomatically. In looking for different conditions to correlate with these two processes, all that can be said is that the formation of kaolin seems to be conditioned by the presence of a heavy growth of vegetation, and that of bauxite by the absence of heavy vegetation and humus, and the presence in the parent rock of sulphides. What chemical significance these contrasts may have, I do not feel at present justified in discussing. Laboratory experiments of a kind not yet attempted are evidently necessary before the central problem of lateritization can be satisfactorily solved. It is possible, however, that the secret processes now in operation for the manufacture of aluminium from felspar might throw an important light on the origin of laterite. In the absence of

[1] Stremme, *Zeit. Prakt. Geol.*, 1908, pp. 122, 443; Wüst, *Zeit. Prakt. Geol.*, 1907, p. 19.

experimental data, the facts given in the present paper may help others to attempt the explanation for which geologists are waiting.

EXPLANATION OF PLATE XXXVII.

East Peak, Sawa Base Camp, Ribawe Mountains, Mozambique, Portuguese East Africa. Lat. 14° 56′ 39″ S.; long. 38° 17′ 10″ E. Height 2,889 feet. The banding of the gneiss and its 'dip' from south to north (right to left) can be seen along the hillside above the hut. The great scars which break up its otherwise smooth surface mark the position of a series of caves which have developed along the direction of dip.

II.—On the supposed case of Tin *in statu nascenti* in the Malay Peninsula.

By W. R. Jones, B.Sc. London, F.G.S., Assistant Geologist F.M.S.

Communicated at the request of the Government Geologist F.M.S.

M. STANISLAS MEUNIER, in a paper entitled "Examen Chimique d'eaux minérales provenant de Malaise. Mineral d'etain de formation actuelle",[1] describes analyses of two waters brought by M. J. Errington De la Croix from Ayer Panas and Cheras, Malay Peninsula, and also of a mineral specimen found in one of the springs. A copy of the original paper is, unfortunately, not available here, but Dr. Bott, in a paper entitled "Thermal Springs of Selangor and Malacca",[2] quotes Meunier as follows:—

"A mineral found in the spring is described, having a specific gravity of 2·1, cavernous and tuberculous structure, whitish grey colour, with small black dendritic patches in it. The composition of this is given as—

	%
Silica	91·8
Water	7·5
Tin oxide	0·5
Iron	0·2
Aluminium	traces
	100·00

"From this the author draws the remarkable conclusion that this substance is a kind of opal similar to geyserite, but containing tin as a peculiar and characteristic constituent.

"He goes on to say that this is the first time that tin has been formed *in statu nascenti*, as it were, viz., in the act of deposition from its mother liquor, and looks upon this as an important contribution to the theory of the formation of tin-ore."

At the suggestion of Mr. Scrivenor, the Government Geologist F.M.S., I visited the above springs with the view of testing Meunier's assertion, and the object of this short paper is to prove that tin has not been found *in statu nascenti* in these or any other springs in Malaya.

[1] Published in J. cx, p. 1085 of the Compt. Rend., and quoted by Dr. Bott.

[2] Dr. W. Bott, F.C.S., F.G.C.S., etc., Journal of the Straits Branch of the Royal Asiatic Society, December, 1891, pp. 43–62.

It is not clear from Dr. Bott's paper whether the mineral specimen analysed by Meunier was obtained from Ayer Panas ('hot water') or from Cheras, and as there are two places named Ayer Panas in Malacca at both of which are hot springs, and as Cheras is north of the State of Malacca and in the State of Selangor, some doubt exists as to the exact locality from which the specimen was obtained. All these springs, however, have been examined recently.

At Ayer Panas, near Jasin in Malacca, there are six hot springs within a circle of about twenty yards diameter, and probably connected together below the surface. The difference in temperatures of these springs is probably due entirely to the different distances from the main spring and to different proportions of surface-water with which they are mixed. The writer visited these springs during dry weather, and this accounts probably for the higher readings he obtained compared with those of Dr. Bott:—

Dr. Bott in August to September, 1890.

No. 1. 45° C. No. 2. 35° C. No. 3. 45° C. No. 4. 52° C. No. 5. 55° C.

W. R. Jones in July, 1914.

Tank A. 56·5° C. Tank B. 52·5° C., 52·3° C.

The springs are in a padi swamp. The smell of sulphuretted hydrogen can be distinguished several yards away from the springs.

At Ayer Panas, near Alor Gajah in Malacca (at the 19th mile on the Tampin road), one spring is enclosed in a bricked well, and the other rises a few feet away.

	Dr. Bott.	*W. R. Jones.*
Water in bricked well	55° C.	56° C.
Water in brook	40° C.	52° C.

The smell of sulphuretted hydrogen is distinct near the springs.

Granite is in situ less than a mile away, and its junction with mica-schist on the Alor Gajah side may be not far from the hot springs. On the Tampin side the junction was seen near the 21¾ mile.

At Cheras, about 3¾ miles from Kajang in Selangor, the hot spring rises in low ground covered with high grass, and in wet weather it is swampy. The highest temperature obtained was 46·25° C. There is a distinct smell of sulphuretted hydrogen in the neighbourhood. Granite is exposed on the road between Cheras and Dusun Tua, and further work would probably show that granite outcrops not far from the Cheras hot springs.

There are hot springs at Dusun Tua in Selangor, and these issue from a fracture in tourmaline-granite. In a bricked well a temperature of 72·1° C. was registered. The smell of sulphuretted hydrogen can be distinguished a hundred yards from the spring on certain days, and the water tastes of this gas.

On a Chinese rubber estate near Ulu Yam in Ulu Selangor a hot spring rises within a few yards of the junction of the granite and mica-schist. The granite contains a little cassiterite in this neighbourhood. Sulphuretted hydrogen is present in the water.

Below are given Dr. Bott's analyses of these waters, and it will be noticed that he has allocated the acids, as was generally done in those days, to their presumed bases.

ANALYSES OF WATERS.

	Ayer Panas, Jasin, Malacca. Dr. Bott.	Ayer Panas, Alor Gajah, Malacca. Dr. Bott.	Dusun Tua. Dr. Bott.	Great Geyser of Iceland.[1]
Total solids in water (in grains per gallon)	18·40	1·7	15·4	
Hardness	2·50	2·5	2·3	
Chlorine	0·70	0·5	0·25	
Free ammonia (per million parts)	0·05	0·04	0·04	
Albuminoid ammonia (per million parts)	0·05	0·05	0·03	
Constituents dissolved in 10,000 parts of water.				
Calcium carbonate	0·160	0·200	0·1357	
Calcium sulphate	0·180	0·140	0·11400	
Magnesium sulphate	0·015	0·025	0·01200	0·042
Sodium sulphate	0·190	0·150	0·09900	1·07
Potassium sulphate	0·085	0·950	0·06300	0·475
Sodium carbonate	0·450	0·550	0·0800	1·939
Ammonium carbonate	0·00018	0·00015	0·00053	0·083
Sodium chloride	0·095	0·075	0·05100	2·521
Potassium chloride	0·006	0·005	0·00400	
Lithium chloride		trace	trace	
Sodium sulphide	0·200	0·019	0·00900	0·088
Hydrogen sulphide	0·025	0·020	0·03200	
Carbon acid	0·585	0·480	0·92000	0·557
Nitrogen	0·085	0·075	0·07000	
Silica	0·780	0·590	0·61200	5·097
Organic matter	0·250	0·295	0·04031	
Boric acid	—	—	trace	
Potassium iodide	—	—	—	

No trace of tin was found by Dr. Bott, and recent tests carried out by Mr. C. Salter, Chemist to the Geological Department F.M.S., and the writer have failed to give any traces of tin in solution in these waters. It is to be noted that Meunier is not quoted by Dr. Bott as having found tin in solution in the water, but seems to have based his conclusion that tin was *in statu nascenti* solely on the result of the analysis of the mineral specimen which he described as "a kind of opal similar to geyserite . . ." The deposition of tin oxide from water containing sulphuretted hydrogen is, as Dr. Bott points out, a chemical impossibility.

Careful search in the neighbourhood of these hot springs has failed to prove the presence of any such mineral deposit, and when it is considered that these hot waters contain less than one part in 10,000 of silica, that they contain other metals in solution, and that they commingle with surface-waters near their outlets, it would be astonishing to find them depositing a mineral having 91·8 per cent of silica and no other metal besides tin-ore and iron. The composition

[1] *Ann. Chem. Pharm.*, 1847, p. 49, quoted by Geikie in *Textbook of Geology*, vol. i, p. 317.

of a geyser water which forms a siliceous deposit is given for comparison.

The soft vegetable and other matter which had accumulated at the bottom of some of the disused wells was collected and tested for tin. No trace of tin was found in a single case.

It is a significant fact that the specimen examined by Meunier gives an analysis strikingly different from all other 'opal deposits' and 'geyserites'. Below three analyses are given for comparison with that of Meunier, and it will be noticed that whereas Meunier obtained traces only of alumina, the other analyses show weighable amounts of alumina and other metals. Out of a long list of analyses of such minerals nothing approaching that given by Meunier has been seen.

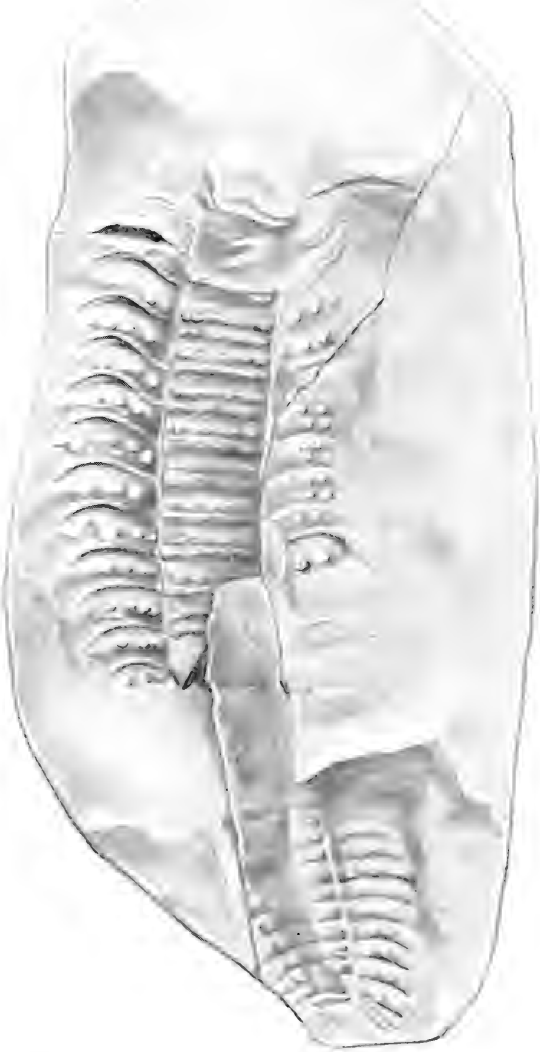
ANALYSES OF SILICEOUS DEPOSITS.

	Opal deposit, Norris Basin.[1]	Geyserite Incrustation, Giant Group, Upper Basin.[1]	Sinter from hot springs, Taupo, New Zealand. J. W. Mallet.[1]	Malayan ? Geyserite, Meunier.
$Si O_2$ . .	93·60	72·25	94·20	91·8
$Al_2 O_3$ . .	1·06	10·96	1·58	traces
$Fe_2 O_3$ . .	trace	0·76	0·17	} 0·2
$Fe O$ . . .	—	0·31	trace	
$Ca O$ . . .	0·50	0·74	—	
$Mg O$ . .	trace	0·10	—	
$K_2 O$ . . .	—	1·66	—	
$Na_2 O$ . .	—	3·55	—	
Na Cl. . .	—	0·36	0·85	
$H_2 O$ . . .	4·71	9·02	3·06	7·5
C . . .	—	0·20	—	
$S O_3$ . . .	—	0·45	—	
S . . .	trace	—	—	
Tin oxide .				0·5
Total .	99·87	100·36	99·86	100·00

Weathered cassiterite-bearing quartz, having a "cavernous and tuberculous structure, whitish grey colour, with small dendritic particles in it", is very common near decomposed schists containing cassiterite-bearing quartz veins, and near weathered pegmatite veins, and there seems little doubt that the specimen sent to Meunier from near the springs was originally derived from one of these sources. Tin-mining has been carried on within a short distance of the hot spring at Cheras. It remains to add that Meunier, as Dr. Bott remarks, "could only work with a small sample sent to him in France," and that "he never saw the springs nor the water fresh from them".

At the bottom of Lahat Tin Mine in the Kinta Valley, Perak, Federated Malay States, a strong spring (not a hot spring) issues from the limestone on which rests the tin-bearing ground, and it sometimes happens that this spring brings up pieces of tin-ore of the

[1] Quoted in *Data of Geochemistry*, F. W. Clarke, 1911.



G. M. Woodward, del. Bale & Sons, imp.

ARTHROPLEURA MOYSEYI, *Calman, sp. nov.*

COAL MEASURES. DERBYSHIRE.

size of one's fist, and containing well-formed angular crystals. This fact has been taken, in some quarters, to support the hydatogenetic theory of the deposition of tin-ore. What happens, however, is that the limestone at Lahat Mine, as it has been proved in several other mines in Kinta, contains tin-ore in situ, and when the limestone has been dissolved by the water the freed ore is brought up by the underground stream. Several pieces of limestone containing crystals of tin-ore were found by the writer at this spot. The water was tested for tin, and no trace of the metal could be found in it. Mr. Salter's analysis of the water is given below:—

Total solids	0·146
Fe_2O_3 / Al_2O_3	0·0030
Ca O	0·05581
(equivalent to $CaCO_3$)	0·09965
K Cl	0·0350
(equivalent to KCO_3)	0·0315

III.—On *Arthropleura Moyseyi*, n.sp., from the Coal-measures of Debyshire.

By W. T. Calman, D.Sc., British Museum (Natural History).

(PLATE XXXVIII.)

THE specimen dealt with in this paper was obtained some years ago by Dr. L. Moysey, of Nottingham, and was sent by him to Dr. Henry Woodward, who has been so kind as to entrust it to me for examination.

Although the specimen has not hitherto been described, it has been several times mentioned in palæontological literature. It was first referred to by Dr. Moysey as "a complete but diminutive example akin to the *Arthropleura armata* of Jordan from Saarbrucken"[1] and was later recorded by him as "*Arthropleura*, n.sp."[2] Herr Andrée, in the second of his two memoirs on *Arthropleura*,[3] makes some observations on it, based on examination of a photograph sent to him by Dr. Moysey. Herr Andrée agrees with Dr. Moysey in referring the specimen to the genus *Arthropleura*, but concludes that it adds nothing to our knowledge of the genus, the photograph evidently not having revealed to him certain features that are clearly visible in the fossil itself. These features are well shown in the accompanying Plate, for which I am indebted to the care and skill of Miss G. M. Woodward.

Arthropleura Moyseyi, n.sp. (Plate XXXVIII.)

Description.—The specimen is contained in an ironstone nodule which has been split longitudinally. The structure is most clearly seen on the half in which the fossil is exposed in relief, but some important details have been obtained from a 'squeeze' kindly prepared for me from the counterpart by Dr. F. A. Bather.

[1] Geol. Mag. (5), v, p. 221, 1908. [2] Geol. Mag. (5), viii, p. 506, 1911.
[3] *Palæontographica*, lx, p. 303, 1913.

About the middle of the fossil the terga of eleven successive somites are visible in their natural connexions. They are transversely elongated plates of nearly uniform size, measuring about 2·5 × 8 mm. where fully exposed, and slightly convex from side to side. Each is crossed by two transverse tuberculated ridges, or rather, perhaps, rows of partly confluent tubercles. The number of tubercles in each row appears to be seven, but the surface has been much damaged and the exact arrangement is hard to decipher. On each side the terga are separated from the pleura by a well-marked groove, at the bottom of which a suture or line of articulation is visible in places.

The pleura are well preserved only on the left side of the body, where twelve (perhaps thirteen) of them can be made out. Each is a sickle-shaped plate, curving backwards to an acute point and measuring about 6·5 mm. from the point to the articulation with the tergum. Anteriorly, the pleura are slightly inclined forwards, but passing backwards along the series they come to lie transversely to the axis of the body. At or near the anterior edge of each is a strong curved ridge defined by a deep groove, behind which the surface becomes gently convex and bears a row of four or more prominent tubercles. Indications of a second row of smaller tubercles are seen on some of the pleura, but in every case the hinder edge is broken by being crushed down on the ridge of the succeeding pleuron.

The anterior portion of the fossil is obscure. Separated from the foremost tergum by a space corresponding to perhaps two somites, is a slightly convex oval area, marked off behind by a double transverse ridge. This area, no doubt, represents the head of the animal, but no further information can be obtained as to its structure or appendages.

Behind the series of somites described above, is a space of some 10 mm. in which no structure can be observed, although the pleuro-tergal grooves seem to be faintly traceable across it. Behind the gap the somites reappear, considerably smaller, and progressively diminishing in size towards the hinder end. About ten of them can be made out, and the pleural plates, which are visible on the right side, become more backwardly directed as they proceed towards the termination of the body, where some indication of a telsonic segment, flanked by a pair of spines, can be faintly traced. In this posterior part of the body the ornamentation is obscure, but tubercles similar to those on the more anterior somites can be seen here and there on the terga and pleura.

The total length of the body, which is slightly curved to the right, is about 60 mm., measured from the anterior margin of the head.

Holotype.—Specimen No. 34, in the collection of Dr. L. Moysey, Nottingham.

Horizon and Locality.—Coal-measures. "Yellow clays in the neighbourhood of the Top Hard Coal, probably some 30 to 40 feet below that seam. Shipley clay-pit, about 1½ miles north of Ilkeston, Derbyshire."

Remarks.—In the form of the pleural plates, their articulation with the terga, the strong crescentic ridge on each, and the tubercles with which they, as well as the terga, are ornamented, the fossil resembles so closely the specimens of *Arthropleura* hitherto described that there can be no doubt that Dr. Moysey was at least approximately correct in referring it to that genus. Whether Andrée was right in supposing it to be a young individual (other specimens referred to the genus being of relatively gigantic size) is less certain. In any case the details of the ornamentation seem to differ from all the described forms, especially in the presence of two transverse tuberculated ridges on each tergum, and in the fact that the ridges on the pleura are nearer the anterior margin, and I propose, therefore, to regard it as representing a new species.

Systematic Position of Arthropleura.—The great importance of the specimen here described lies in the fact that it gives, for the first time, information regarding the general form of the body and the total number of somites. In this individual the number of post-cephalic somites cannot have been less than twenty-eight and may have been more. This enables us to say with confidence that, whatever the affinities of *Arthropleura* may be, it is certainly not an Isopod. Andrée, who has recently discussed the systematic position of the genus, comes to the remarkable conclusion "das in der *Arthropleura* ein Isopoden-Typus vorläge, bei welchem die Sonderung in Thorakal- und Abdominalsegmente noch nicht erfolgt ist".[1] It is very difficult to discover, in the course of Andrée's two lengthy memoirs, on what conceptions of Malacostracan phylogeny this conclusion is based. It can hardly be seriously contended nowadays that the Isopoda are the most primitive group of the Malacostraca, and that all the other Orders have been derived from them; the alternative hypothesis, which Andrée in certain passages seems to adopt, is that the common characters of the Malacostraca—the fixed number of somites, the delimitation of thorax and abdomen, and so forth—have been acquired by the Isopoda independently of the other Malacostraca. This view will hardly commend itself to anyone who realizes how many structural characters link the Isopoda, by way of the Tanaidacea, with the Cumacea and the Mysidacea.

The resemblances between *Arthropleura* and the Devonian *Oxyuropoda* were pointed out by Carpenter & Swain in their paper on the latter genus,[2] and more fully by Andrée.[3] If it be admitted, therefore, that *Arthropleura* is no Isopod, the doubts that have been cast on the Isopodan nature of *Oxyuropoda* gain in strength.

The characters of *Arthropleura*, and more especially the very remarkable structure of the sternal surface as described by Kliver[4] and by Boule,[5] seem to have no close parallel among recent Arthropoda. It may be a Crustacean of a type hitherto unknown, it may even be a very generalized and primitive kind of Myriopod; but our present knowledge does not seem to justify any more definite

[1] *Palæontographica*, lvii, p. 86, 1910 ("that in *Arthropleura* we have an Isopod type in which the separation into thoracic and abdominal segments has not yet taken place").

[2] Proc. Roy. Irish Acad., xxvii, B (3), p. 65, 1908.

[3] *Palæontographica*, lvii, p. 92, 1910.

[4] *Palæontographica*, xxxi, p. 14, pl. iv, 1884.

[5] Bull. Soc. Industrie Minérale, St. Etienne (3), vii (4), p. 630, pl. lv, 1893.

statement as to its systematic position than that it is an Arthropod *incertæ sedis.*

EXPLANATION OF PLATE XXXVIII.

Arthropleura Moyseyi, n.sp. × 2. This figure has been prepared, in the main, from that half of the nodule in which the fossil is exposed in relief, but certain details have been added from a 'squeeze' made from the counterpart.

Nodule obtained from yellow clays below 'Top Hard Coal', Coal-measures, Shipley Clay-pit, Ilkeston, Derbyshire. Original preserved in the collection of Dr. Lewis Moysey, B.A., M.B., F.G.S.

IV.—Sedgwick Museum Notes.

Strickland's Collection.

By F. R. Cowper Reed, Sc.D., F.G.S.

It may be of interest to the readers of the Geological Magazine to know that the specimens collected by Mr. H. E. Strickland during the years 1835–6 in the Ionian Islands, the Bosphorus, and the neighbourhood of Smyrna are now preserved in the Sedgwick Museum, Cambridge. They comprise the fossils and rocks to which he referred in the following papers published many years ago in the Transactions and Journal of the Geological Society:—

1. "Geology of the Thracian Bosphorus": Trans. Geol. Soc., ser. ii, vol. v, pt. ii, pp. 385–91, 1840 (read November 30, 1836).
2. "Geology of the Neighbourhood of Smyrna": ibid., pp. 393–402 (read April 5, 1837).
3. "Geology of the Island of Zante": ibid., pp. 403–9 (read November 1, 1837).
4. "On a Tertiary Deposit near Lixouri in the Island of Cephalonia": Quart. Journ. Geol. Soc., vol. iii, pp. 110–13, 1847 (read May 3, 1837).

1. The Lower Devonian fossils from the Bosphorus were named by Murchison and Sowerby in the paper quoted, and apparently were regarded as indicating a Silurian age for the beds. They are of special interest as the first ones ever brought back to England from that region for scientific study; and they include several of the species subsequently described from these beds by De Verneuil, Roemer, and Kayser. The Tertiary fossils recorded and roughly identified by Strickland from the locality termed Baloukli belong to the Sarmatian stage, and amongst them may be recognized the characteristic shell *Ervilia podolica.* These beds are described as overlaid by freshwater limestones, and the fossils which the latter contain appear to be similar to those recorded by Hochstetter from the same district.

2. The plant remains from the neighbourhood of Smyrna are probably similar to those described by Unger from these parts. Dr. Arber is now examining them.

3. The fossils from the Mesozoic and Tertiary beds of Zante are in a poor state of preservation, and require further study in the light of the work done by Fuchs and Renz.

4. The Pliocene Mollusca collected by Strickland from Lixouri in the Island of Cephalonia are well preserved, and include the original type-specimens (one of each species) on which his new species *Fusus filamentosus* and *Mitra juniperus* were based. Text-figures of these shells were given in the paper mentioned. The existence and present resting-place of these types had apparently been unknown until their recent rediscovery and recognition in the Sedgwick Museum.

There are also some British shells in Strickland's collection to which reference may here be conveniently made.

1. The original type-specimen of Strickland's species *Unio antiquior*, from the 'Fluviatile Drift' of Cropthorne, Worcester, of which a text-figure was given by Sir W. Jardine in his *Memoirs of H. E. Strickland* (London, 1858), p. clvii, and of which a description was given in the same work on p. 97, has been recently identified in the Sedgwick Museum.

2. The specimens from the Pliocene of the Isle of Man on which Strickland founded his species *Fusus Forbesi* and *Nassa pliocena* (Proc. Geol. Soc., vol. iv, pt. i, pp. 8, 9, 1843) have also been discovered in his collection. They were mounted together on the same tablet with some other broken shells of doubtful reference, and all were labelled *Fusus Forbesi*, while one good specimen of *N. monensis*, Forbes, which was also described in the same paper by Strickland (op. cit., p. 8), was mounted separately with a broken fragment and labelled *Nassa pliocena*. This confusion was pointed out to me by Mr. F. W. Harmer, who has recently described and figured typical specimens of *N. monensis* (*Pliocene Mollusca*, pt. i, p. 74, pl. iv, figs. 7, 8, 1914). Strickland published his specific definitions of *F. Forbesi* and *N. pliocena* without figures, which is unfortunate; but as his descriptions are fairly minute and precise, and as we have the very few actual specimens in his collection which he used in drawing up his definitions, we are enabled to identify and separate the type-specimens of the respective species without hesitation. There are only two examples of each which are fairly well preserved. The mistake in the mounting and labelling of these specimens seems to have been made at an early date (but by whom is unknown); for Sir W. Jardine, in 1858, in his *Memoirs*, to which reference has been made, gave four text-figures (op. cit., p. ccxxviii) of four of the specimens now in the Sedgwick Museum; two of these (figs. 1) were called *F. Forbesi*, and two of them (figs. 2) *N. pliocena*. The two left-hand figures (figs. 1) represent shells belonging to *F. Forbesi*, but the right-hand and smaller one of fig. 2 is *N. monensis* as identified by Mr. Harmer; the other fig. 2 (second one from the right) is the broken fragment mounted with it of which the specific reference is doubtful. The true *N. pliocena* was thus not figured by Sir W. Jardine, and under these circumstances it is of importance that the actual specimens which Strickland used in describing this species have been discovered. Lamplugh (Geol. I. of Man, Mem. Geol. Surv., 1903, pp. 336, 475) includes *N. pliocena*, Strickl., in *N. serrata*, Brocchi

V.—Some Points in the Eolithic Controversy.[1]

By S. Hazzledine Warren, F.G.S.

The controversy which has raged round the problem of the Eoliths seems little nearer a satisfactory solution than it was upon the publication of Sir Joseph Prestwich's papers of 1889, 1891, and 1892.[2] The present article is an endeavour to place certain sceptical considerations before the readers of the Geological Magazine.

In two papers published by the Anthropological Institute,[3] I showed that crushing and mechanical movement under pressure were capable of reproducing the edge-chipping which is characteristic of the eoliths of Kentish type. One of the most notable forms produced by such processes is that of the chipped notch, either single or in various combinations, such as the double notch with point (often called the bow-shaped scraper), two notches crushed out from opposite sides of a tabular flint producing an astonishing simulation of a drill with reverse working, or notches in combination with other edge-chipping.

It is understood that mechanical force can only effect a reproduction of an eolith when operating upon suitable raw material: that is to say, upon flints of plano-convex or tabular form such as those of which the Kentish eoliths are made. In fact, it is only in working upon this special class of raw material that an eolith of this type can be formed by any process, whether by design or accident.

With regard to the criticisms of Mr. F. J. Bennett,[4] it is true that my theory could not stand upon the results of a machine, if this were in the way in which it is represented by him. I have used many different processes in the application of mechanical force in order to investigate the chipping properties of flint, and have attempted, as will be seen in the sequel, to apply this knowledge to what we see of the processes of nature.

Again, Mr. Bennett says that suppose I could perfect this method so as to produce palæolithic and neolithic implements, would this prove that these implements were non-human in origin? In answer to this one can only say that mere mechanical force, however it may be applied, *does not produce true implements.* I do not therefore think that Mr. Bennett's argument carries much weight. We cannot in science go into the question of what we might believe in the event of the facts which are the foundation of our theories proving to be the opposite of that which they are observed to be. If such circumstances were realized I think we should most of us be constrained to modify our opinions. We must surely make our theories accord with the facts as they are, not with imaginary facts which might conceivably be but which are not.[5]

[1] This article, owing to pressure of other matters, has been very long delayed, for which circumstance the Editor offers his apologies to the author.

[2] J. Prestwich, Quart. Journ. Geol. Soc., vol. xlv, p. 270, 1889; vol. xlvii, p. 126, 1891; Journ. Anthrop. Inst., vol. xxi, p. 246, 1892.

[3] S. H. Warren, *Man*, 1905, 103; 1906, 3; Journ. Anthrop. Inst., vol. xxxv, p. 337, 1905.

[4] F. J. Bennett, Geol. Mag. 1913, p. 47.

[5] In the same number of the Geological Magazine (1913, p. 46) a letter also appeared from Mr. J. Reid Moir in which he raised certain

The main line of Mr. Reid Moir's argument is this[1]: that we, who take the sceptical side, have no case until we can show reproductions of the sub-Crag chipped flints made by an unguided natural force. This is a perfectly safe challenge, and if it is in itself a sound argument it is unanswerable, for I have never used an unguided natural force in the conduct of flint experiments. But this which is true of my experiments is equally true of those which have been conducted by Mr. Reid Moir.

But is it a sound argument? Let us apply it to other cases. Firstly, let me say: "I claim a chair to be an artificial product, and anyone who claims a chair to be natural must produce one made experimentally by an unguided natural force." This seems to be right, and to confirm the soundness of my logic. But suppose I replace the word 'chair' by 'crystalline diamond'. Can anyone reproduce a perfect crystal of a diamond, with its polished facets, by an experimental process coming within the designation of an unguided natural force? I think not. Such things, if they are to be done successfully, require great care in the arrangement and control of the methods adopted.

In fact, to speak of experimenting with an unguided natural force is almost a contradiction in terms. The object of scientific experiment is to discover what will happen under definitely known or controlled conditions.

Mr. Reid Moir has fallen into the error of supposing that a few inadequate experiments can show everything that Nature can do. Experiments cannot easily reproduce natural conditions, and if they do not adequately reproduce natural conditions they cannot *directly* show the product of those conditions.

Sir Ray Lankester has graphically described the grinding of one flint against another beneath the pressure of an ice-sheet in the formation of the striations found upon their surfaces. Have the experiments, upon the negative results of which Mr. Reid Moir relies, reproduced such conditions? Of course not![2]

Mr. Reid Moir argues that because certain special and very limited experiments have not produced a given result, that therefore natural agencies cannot produce that result. If I had argued (upon the same method but in the contrary sense) that because eoliths can be reproduced by mechanical means, *and without taking other evidences into account*, that therefore natural agencies have made the eoliths, the criticism of my opponents would be justified. This has

personalities. These were the outcome of an unfortunate misunderstanding, and I have Mr. Moir's authority for stating that he has withdrawn them. I am particularly glad of this, as one is naturally desirous of discussing a theoretical question upon its own intrinsic merits, and in a spirit that is personally friendly towards those from whom one differs.

[1] J. Reid Moir, Abstracts Proc. Geol. Soc., November 28, 1913, p. 16; and elsewhere.

[2] In this I am taking the theory of my opponents as it stands. It may be correct, but personally I am of opinion that the striations in question are due essentially to solifluction, possibly, but not necessarily, assisted by the additional weight of snow or ice. From the point of view of the flint chipping the matter is not important, as either the soil or the ice would furnish the necessary pressure.

not been my argument, as anyone who will read my published papers may find.

In my opinion, the object of *the investigation of flint is to ascertain by experiments its chipping properties.*

This investigation has shown, as I have indicated in an earlier part of this article, that when suitable raw material is subjected to a force of crushing or of differential movement under pressure eolithic chipping inevitably takes place.

Now one of the most notable features which is associated with the eoliths in the field is the striation of the surfaces of the flints. Whether this striation be due exclusively to ice-action, as some have claimed, or whether it be more commonly due to the active process of solifluction or *soil-abrasion.*[1] (as I have previously suggested that it might be named), does not affect the immediate question of the eoliths. In either case, striation of the flint surfaces indicates movement under pressure.

I venture to ask that if experimental movement under pressure inevitably produces eolithic edge-chipping, is it so unreasonable to suppose that natural movement under pressure will also have the same chipping effect when operating upon similar material?

I hope to describe before long the experiments which I have been conducting for the purpose of discovering the amount of chipping produced by differential movement under various pressures.[2] And also the comparison of this with the amount of the subsoil pressure which falls upon stones in different soils according to their superficial area and their depth beneath the surface. This is a somewhat complicated subject and one which cannot be dealt with adequately within the compass of a short article. I will only say here that there is no inherent difficulty, so far as the necessary pressure is concerned, in the chipping of the Kentish type of eoliths by the action of soil-abrasion during the sliding or solifluction of drift deposits.[3]

With regard to the larger chipping upon the sub-Crag flints, it is perfectly true that this has not been reproduced experimentally by mechanical force. But I am unable to follow Mr. Moir in viewing this as a matter of such great moment, for the simple reason that no experiment of differential movement under the pressure which exists beneath 20 or 30 feet of drift, to say nothing of the weight of an ice-sheet, has yet been made upon flint. In making such experiments it would be necessary to take into account the structure, size, shape, and flaking qualities of the raw material used; for a result which is inevitable upon one piece of flint is unattainable upon another.

For the present one can only judge of the sub-Crag flints upon general lines, and by inference from the known lesser to the unknown greater. In my judgment the sub-Crag chipping is only what one might expect to take place where forces of greater magnitude are operating upon larger material.

[1] S. H. Warren, Journ. Anthrop. Inst., vol. xxxv, p. 349, 1905.

[2] Since this was written the paper has been read at a joint meeting of the Royal Anthropological Institute and the Prehistoric Society of East Anglia on February 17, 1914, but it is not yet published.

[3] See also Abstracts Proc. Geol. Soc., November 28, 1913.

But coming again to more general points, it is argued that the palæoliths cannot have been the first human implements, but that they must on *a priori* grounds have been preceded by an 'eolithic' stage of culture. It is true that everything must have its beginning, but at the same time we do not find in the development of human arts and crafts that any method becomes dominant until it has reached a certain degree of excellence and practical usefulness.

The most primitive implement of stone is the simple pebble, used for purposes of hammering or crushing.[1] In its simplest form it is not an artifact, and cannot always be determined as a human implement. It goes right through the human period, and is still occasionally used by ourselves at the present day.

Apart from this, the most primitive implements among modern savages are not implements of stone, but those made of wood, thorns, the teeth and claws of wild animals, shells, and the like. We may call this culture the *age of wood.* There are races living to-day who have scarcely reached the stone age—or, as is perhaps more probable, who have gone back by a process of atavism to a condition which is practically a pre-stone-age culture.[2]

The age of metal did not supersede the age of stone until the working of metal had sufficiently advanced to make its general use advantageous. And that, I think, is the general order of things; it seems inevitable that it should be. Why is it theoretically necessary for the passage from the age of wood to the age of stone to have been an exception?

One of the first needs of mankind in all ages is a cutting instrument.[1] We do not find an important stage in human cultural evolution represented by vast numbers of abortive attempts at making cutting instruments of metal. Yet it is confidently alleged that the earliest phase of the stone age ought (*a priori*) to be represented by instruments of stone that will not cut, and the eoliths are held to fulfil this expectation. I do not understand why the earliest group of stone implements should be incapable of cutting.[3]

I am not forgetting that large numbers of the eoliths—supposing them to be human implements—belong to the scraping group of cutting tools. But even scrapers require to have a definite edge, which is often not very apparent on the eoliths.

[1] [It may not be without interest to record that the late Dr. Richardson (F.R.S. Tas.) informed me (many years ago) that on the old beaches along the coasts of Tasmania he had found *very ancient native 'middens'* marked by heaps of bivalve shells which had been opened with *sharp-edged stones*; in other spots the middens consisted of broken univalves (*Tritons*, etc.) whose whorls had been crushed with *round stones.* In each case the appropriate implement was found at that locality with the shells of the particular molluscs upon which the natives had subsisted.—Ed. Geol. Mag.]

This is a very interesting point. Taking Dr. Richardson's conclusion with regard to the "sharp-edged stones" as correct, they come within the group of cutting instruments. The round stones belong to the primitive pebble-hammers. The eoliths cannot claim to belong to either group.—S. H. W.

[2] W. J. McGee, "On the Seri Indians": Bull. Bureau Amer. Ethnol., 17, pt. i, 1896.

[3] See also G. & A. de Mortillet, *Le Préhistorique Origine et Antiquité de l'homme*, 3rd ed., p. 143, 1900. The argument here is that the Chelléen instrument is essentially primitive.

If the eoliths are scrapers, the group is not primitive, but highly specialized. It hardly seems credible that such high specialization of form (and presumably of function) should be reached with implements that, viewed as practical tools, are less efficient than naturally broken stones which may be picked up ready made.

It is urged in defence that if we do not know the uses of the eoliths, neither do we know the uses of the palæoliths. This is hardly the point; *it is not their uses, but their usefulness.* In contrast with the eoliths, the early palæoliths, as so ably shown by De Mortillet, are primitive and generalized in form, and yet they are efficient cutting tools.

We must now consider the appeal to history. Practically every one who has written in defence of the eoliths has made a strong point of the appeal to the history of the objections formerly urged against the palæoliths. It seems to me that every case must be judged upon its own merits; to give an illustration, we cannot prove that *Eozoon* is truly organic by the appeal to history; to the history, that is, of the controversy which formerly raged round the rival claims of 'sports of nature' and 'petrifactions'. Further, in pouring our contempt upon those who formerly opposed the contemporaneity of man with extinct animals we must not forget that the greater number of the supposed facts upon which the earlier speculators based their belief have long since been discredited and forgotten. We now know that Mr. Frere's discovery in 1797 of flint implements with remains of the Mammoth at Hoxne was correct, but it was not only—or even perhaps chiefly—upon such evidences that the earlier speculators really based their belief, but rather upon such things as the 'homo diluvii testis' of Œningen, which is now known to be an extinct salamander. The Rev. J. McEnery's discovery in 1825 of flint implements and extinct mammalia at Kent's Cavern has also been fully confirmed by Pengelly, but if we go a little more carefully into history we shall find that in a large number of cases the side of the opposition was right and has won the day.

So that if the appeal to history were admitted as scientific evidence (which I do not think it is) it would be at best a dangerous two-edged sword to wield.

A better argument that has been urged against my point of view by Professor Schwartz and Sir Hugh Bevor[1] is that it entails the attribution of chipping, which is in all cases essentially similar, to different natural agencies when found in various geological deposits. These authors argue that the only cause which can be postulated for this uniformity of effect, wherever it may be found, is Man.

Unfortunately, another of my opponents, Mr. Reid Moir,[2] urges, with equal show of reason, that the groups of eolithic chipping which are found in different geological deposits are essentially different from each other. This author argues that natural causes must

[1] A. Schwartz & H. R. Bevor, Mem. and Proc. Manchester Lit. and Phil. Soc., vol. liii, p. 29 of reprint, 1909.

[2] J. Reid Moir, Abstracts Proc. Geol. Soc., November 28, 1913, p. 16; and elsewhere.

always chip flints in the same way, and that it is only man who can chip them in different ways.

Thus my opponents in traversing each other show the logical unsoundness of their own arguments.

Another objection which has been raised, notably by Mr. C. J. Grist,[1] against the theory of the origin of eoliths by movement under pressure in geological deposits, is that there are certain superficial drifts in which solifluction has had an obvious share which at the same time do not yield eoliths. One must take into consideration in such cases—

1. Whether the drift in question contains an abundance of raw material of suitable size and shape for the making of eoliths.
2. Whether the flint surfaces show striations similar to those which are characteristic of the 'eolithic' Chalk down drifts.

If these two conditions are realized, then the case is a valid objection against my theory; and it requires to be given its due weight. If, on the other hand, this is not so, then the objection has no application against my theory, because the conditions of that theory are not fulfilled. This particularly refers to the eoliths of Kentish type; but, as I endeavoured to show in the paper published in 1905, there are other groups of eoliths, standing somewhat apart from these, which I believe owe their form to different causes.

In general answer to the objections of Professor Schwartz and Sir Hugh Bevor, Mr. Reid Moir and Mr. C. J. Grist, which are referred to above, it is my experience that *the characters of the edge-chipping of the group of eoliths found in any geological deposit is dependent partly upon the character of the raw material which is locally available and partly upon the geological forces which have acted upon that material.* The direct evidences for the operation of these forces are found, broadly speaking, in striation of the flint surfaces indicating ice- or soil-abrasion, and contusion and reticulation of the surfaces indicating water-abrasion.

If the eoliths were human implements it appears to me that we should expect that their characteristics would be independent of associated geological forces, but would be dependent upon the relative ages of the deposits containing them. As a matter of fact we do not find that earlier deposits consistently contain more primitive eoliths and later deposits more advanced eoliths. In a broad view of the evidences, the characteristics of eolithic groups bear no discoverable relation to the age of the deposits containing them.

There are also other processes and conditions of flint chipping which have their own special characters, such as dead crushing without movement,[2] and consequently without associated striations, but the two processes mentioned above are generally the most important.

There is only one way to become acquainted with the characters of flint chipping which belong to different mechanical processes, and that is by first-hand knowledge gained by following the work out for oneself in the simple endeavour to find the truth.

[1] C. J. Grist, Journ. Anthrop. Inst., vol. xl, p. 198, 1910.

[2] This is particularly evident in the Reading Beds at Harefield, where I first found these forms on a recent visit of the Geologists' Association.

We have still so much to learn that it is perhaps rash to be too definite; at the same time I have no hesitation in expressing my opinion. I believe that when the subject of flint chipping comes to be understood upon a scientific basis it will no more be possible to regard the eolithic groups (as a whole) [1] as human implements than it is possible, now that anatomy is understood, to regard the fossil salamander of Œningen as being veritably the skeleton of a human being who witnessed the deluge.

In conclusion, I would like to express my indebtedness to the articles which have been published on the sceptical side by Mr. F. N. Haward and Mr. W. H. Sutcliffe, to the evidences brought before the British Association by Professor Sollas, and to other papers published in this country and upon the Continent.[2]

The figure shows a piece of tabular flint with two notches crushed out of its edge by pressure against two pebbles, as illustrated by the photograph. The half-circle by the side has a diameter of 1 inch, and is placed there to show the scale.

[1] The question of the selection of, say, 2 per cent (as has been suggested) of the eoliths as being more probably human implements than the remainder is a very difficult one. There is much to be said in its favour, but, on the other hand, the members of the eolithic groups have so much essentially in common that to my mind it seems more logical to consider that they must stand or fall together.

[2] F. N. Haward, Proc. Prehist. Soc. East Anglia, vol. i, p. 185, 1912; vol. i, p. 347, 1913; W. H. Sutcliffe, Mem. and Proc. Manchester Lit. and Phil. Soc., vol. lvii, No. 7, 1913; M. Boule, *L'Anthropologie*, vol. xvi, p. 266, 1905; W. G. Smith, *Man*, 1907, 99; 1908, 53; H. Breuil, *L'Anthropologie*, vol. xxi, p. 385, 1910; P. Sarasin, *Verhand. Naturfor. Ges. Basel*, vol. xxii, p. 1, 1911. Further references may be found in these papers.

REVIEWS.

I.—Prehistoric Man.

The Antiquity of Man in Europe. By James Geikie, LL.D., D.C.L., F.R.S. 8vo; pp. xx, 317, with 4 maps. Edinburgh: Oliver & Boyd, 1914. Price 10*s*. 6*d*.

PROFESSOR JAMES GEIKIE has made the Munro Lectureship, which he held in 1913, an opportunity for restating his views on the interpretation of the Pleistocene deposits of Western Europe, with numerous references to the latest discoveries. The result is a most readable volume, which will be welcomed equally by the professed geologist and by the intellectual onlooker who desires a broad statement without too much confusing detail. As might be anticipated from the nature of the author's own researches, the geological evidence alone is dealt with; and the caution engendered by these lifelong researches prevents Professor Geikie from giving much encouragement to those who venture to express geological time in terms of years. He is satisfied when he has pointed out how many and how great changes have taken place in this part of the world since man first appeared here.

It is clear that man has lived in Europe since the beginning of the Pleistocene period, but Professor Geikie thinks that more satisfactory evidence is needed than that of chipped flints before his presence in the Pliocene becomes certain. He specially doubts the evidence of the so-called eoliths, for those found "in the older Tertiary formations cannot be distinguished from those met with in Miocene, Pliocene, and even Pleistocene deposits". Hence, if we accept them "as proofs of man's existence in Eocene and Oligocene times, we must admit that in his case—and in his case alone—evolution must have been at a standstill during a prodigiously extended period".

The first lecture deals with the animals and plants which lived in Europe during Pleistocene times, and is illustrated with several good woodcuts and photographs. The conclusion seems inevitable that considerable changes of climate have occurred—that the theory of great annual migrations to account for the apparent mingling of mammalian remains is negatived by the evidence of the plants, "which could not have indulged in such feats of travel."

The next two lectures refer to the testimony of the caves, and briefly describe the 'culture-stages' recognizable in the succession of stone implements. The interpretation of the cave-deposits themselves is specially discussed from the geological point of view, and many interesting results are arrived at. A description of the Schweizersbild cave, near Schaffhausen, Switzerland, shows tundra, steppe, and forest faunas in succession from the later part of the Palæolithic to the early part of the Neolithic period.

The lecture on the river-drifts gives a concise account of Commont's latest researches in the valley of the Somme, and Professor Geikie concludes that there must be some accidental mixing of the mammalian bones in the deposits hitherto studied in the valley of the Thames. He also emphasizes the importance of Mr. Hazzledine

Warren's discovery of an Arctic plant-bed in the valley of the Lea, which seems to date back to a late phase of the Pleistocene period.

Glacial phenomena and the glacial deposits form the subject of the remaining lectures, and there is much interesting matter which has not hitherto been accessible in so concise a form. The short account and interpretation of the breccias and associated deposits round the rock of Gibraltar are specially welcome, and it would be interesting to test the results by reference to other parts of the Mediterranean area.

Professor Geikie concludes with a valuable summary of the history of the Pleistocene period—its succession of glacial and interglacial episodes—as he understands it, and provides a clear statement which will be very acceptable to students who are occupied with the examination of superficial deposits. The short appendix referring to recent discoveries and various technical matters will also prove helpful.

II.—The Geology of Lyme Regis and Charmouth.[1]

THE Geologists' Association of London has again surpassed itself. Not content with issuing 6 in. maps to illustrate Rowe and Sherborn's contributions to the Chalk of England, they have now published W. D. Lang's paper on the coast of Lyme Regis and Charmouth, and illustrated that with maps on the scale of 25 inches to the mile. This is indeed geology *de luxe*, and enables the amateur and the professional both to collect and zone their specimens with precision of the highest value in any future work. Mr. Lang's text occupies some sixty pages, and appears to be a model of conciseness and clarity, in which the Lias, the Cretaceous, and the post-Cretaceous beds are fully dealt with. The maps, printed by Weller & Graham from Ordnance Survey transfers, are all that could be desired, and are indispensable to any one visiting the district. Truly the members of the Geologists' Association are fortunate in their publications when so much solicitude is shown for the needs of the local worker. We believe that this is the first occasion on which 25 in. maps have been printed and published by any authority.

III.—The Wilds of Maoriland. By J. M. Bell, M.A., Ph.D. pp. xiii + 253, with 8 coloured plates, numerous illustrations, and maps. London: Macmillan, 1914. Price 15*s*.

ALL those geologists and geographers who are acquainted with the excellent work done by Dr. Mackintosh Bell during the six years spent as Director of the Geological Survey of New Zealand will turn with interest to this book, which gives in a somewhat popular form an account of his wanderings in that fascinating country. It is clear that geological work in New Zealand involves not only a laborious existence, but difficulty, privation, and even danger in the less-known and mountainous regions. In the more interesting parts

[1] Proc. Geol. Assoc., vol. xxv, pts. v, vi, 1914, pp. 360, plates 39 and 40, folding table, and 3 coloured geological maps and 1 vertical section between West Haye Water and Lyme Regis. Issued October 27, 1914. Price 5*s*. complete.

of the country there are no bridges over the rapid rivers, and the roads are of the most primitive type; shelter and food also are hard to find. But the geology and scenery well repay the hardships incurred. In the North Island there are the wonderful volcanoes of the Taupo zone: it may be mentioned that the map of the Tarawera region in this book is specially clear and interesting, and a good account is given of the eruption in 1886 that destroyed the ever-to-be-regretted pink and white terraces. Again, in the South Island there is the wonderful glacier system of the Southern Alps; of these some beautiful pictures are provided. Perhaps, however, the most striking feature of the topography of New Zealand is the district of Milford Sound in the extreme south-west. Here is found fiord scenery even more wonderful than that of Norway.

The graphic descriptions of scenery here given are illustrated by many photographs and artistic coloured plates; there are also two excellent maps, one of the central part of the Southern Alps (the glacier district) on a fairly large scale, the other a general map of the whole island, indicating the regions described in the text.

The last chapter, on the geography and climate of New Zealand, gives an excellent short account of the chief physical features of the islands. It is pointed out that perhaps no other country in the world can show such a wonderful variety of physical features, and yet the whole area of the Dominion is less than that of the British Isles. New Zealand is as yet essentially a pastoral country, but its mining is of increasing importance, and the day will surely come when the enormous water power available in the mountains will be turned to account to supply manufactured goods for the great population that must eventually grow up both in the pastoral parts of the country itself and still more in Australia, where over vast areas water power is conspicuously lacking.

This interesting and well-got-up book should do much to draw the attention of geologists, explorers, and mountain climbers to a field where all will find much scope for their energies, with a probable harvest of results of scientific and practical value.

IV.—Canadian Geology.

Kewagama Lake Map-Area, Quebec. By M. E. Wilson. Canada, Department of Mines, Geological Survey Memoir 39. pp. vi + 139 and map. 1913.

The area described in this memoir lies in North-Western Quebec, and is part of the great glaciated pre-Cambrian plateau which occupies so much of Canada. The basal rocks consist of an Archæan complex, which includes metamorphosed sediments and volcanic rocks, and batholithic intrusions of granite and gneiss. The former have generally been correlated with the Keewatin, but the author considered this correlation to be somewhat doubtful, and suggests that the name *Abitibi* group be substituted. In the northern part of the region the rocks belonging to this group are largely of volcanic origin, including basic to acid types, but more especially those of intermediate composition. The ancient lavas of the Abitibi very commonly possess the pillow or ellipsoidal structure which has now been recognized in so many different parts of the world. A very useful bibliography and discussion of the origin of pillow lavas is given, and the author comes to the conclusion that, as elsewhere, the structure is to be attributed to extrusion under water. By contact metamorphism due to later batholithic intrusion the more basic rocks have been transformed into hornblende schists and amphibolites, and the more acid types into sericite schists. In the southern part of the area, the Abitibi group is represented by sediments more or less metamorphosed. They are distinguished as the *Pontiac* series, their stratigraphical position relative to the volcanics being still unsettled.

Into the Abitibi rocks granitic batholiths are intrusive. Locally the granite passes into diorite, and where the rock is rich in hornblende the change of composition can often be traced to the assimilation of basic volcanic rocks. To quote the author: "There appears to be complete gradation from blocks of rocks (xenoliths) which undoubtedly belong to the Abitibi group to hornblende granite." The intrusions made room for themselves by lifting and thrusting aside the surrounding rocks and by sub-crustal stoping, but the relative importance of these three methods are, unfortunately, not discussed.

Lying unconformably on the denuded surface of the rocks already described is a group of clastic sediments which constitute the *Cobalt* series. At the base of the series and often at the summit conglomerates are found. Their possible modes of origin are thoroughly discussed, and the evidence (undecomposed and angular character of the pebbles and the abundance of 'soled' and scratched examples) is held to point to a glacial origin. The intermediate beds are of lacustrine origin and seem to represent an interglacial episode. The whole series is classed as Huronian, no more detailed correlation being possible.

Of probably later date than the Cobalt series are a large number of diabase dykes and an isolated and unique intrusion of syenite porphyry.

The author describes the mantle of glacial and post-glacial (lacustrine) deposits, and concludes with some account of the ore deposits and economic possibilities of the district. The outstanding features in the geological history of the region appear to have been—(1) The stupendous vulcanism of its early history. (2) The undisturbed continental character of the region, interrupted only by a short period of marine submergence in Silurian time. (3) The occurrence of two prolonged eras of denudation, terminated in each case (Huronian and Quaternary) by continental glaciation.

ARTHUR HOLMES.

V.—THE ARCHÆAN GEOLOGY OF RAINY LAKE RE-STUDIED. By ANDREW C. LAWSON. Canada, Department of Mines, Geological Survey Memoir 40. pp. vii + 115 and map. 1913.

IN 1887 Dr. A. C. Lawson described the pre-Cambrian geology of the Rainy Lake region of North-Western Ontario in a memoir which has since become classic. In it he described two series of metamorphic rocks which were proved to be older than the 'Laurentian': the Coutchiching, a series of mica-schists and para-gneisses, and above it the Keewatin, a series made up largely of volcanic rocks. The conclusions then arrived at as to the stratigraphical position of the Coutchiching have been called in question by the United States Geological Survey and by the International Committee on Geological Nomenclature. They denied the existence of such a series *below* the Keewatin, and decided that on at least one line of section the rocks referred to the Coutchiching were certainly stratigraphically higher than parts of the Keewatin. This controversy naturally led to a re-examination of the district by Dr. Lawson, and his revised conclusions are now before us. In all its essentials he maintains his original position, and having forcibly presented his case with a mass of detailed and convincing field evidence, he challenges his critics to deny the superposition of the Keewatin upon the Coutchiching as he mapped them a quarter of a century ago.

The International Committee of 1905 decided that the term 'Laurentian' should be restricted to the granites and gneissose granites which antedate or protrude through the Keewatin and which are pre-Huronian. Since then it has become increasingly evident that a great proportion of the igneous rocks mapped as 'Laurentian' are of post-Huronian age. In the Rainy Lake region at least two periods of granite intrusion, widely separated in age, have been recognized. For the older of these Dr. Lawson proposes to retain the term Laurentian in accordance with the now accepted definition, and for the later (post-Huronian) he suggests the term *Algoman*, from the old district of Algoma, in which such intrusions extensively occur.

Dr. Lawson discusses the mechanics of batholithic intrusion as illustrated in his area, and comes to the conclusion that the facts are somewhat difficult to harmonize with Daly's conception of stoping on a large scale. The folded and faulted structures of the roofs are suggestive of a mode of intrusion analogous to that of a laccolith.

Only two divisions of the Huronian formations are recognized, the Animikie, as shown in the classification given below, being separated from the Upper Huronian (Middle Huronian of Van Hise and Leith) by the intrusion of the Algoman granites and by the immensely long period of erosion which followed. The pre-Cambrian sequence suggested by Dr. Lawson is as follows:—

ALGONKIAN	Keweenawan.	
	Unconformity.	
	Animikie.	
	Eparchæan interval.	
ARCHÆAN	Algoman granites, gneisses, etc.	
	Irruptive contact.	
	Upper Huronian.	
	Unconformity.	
	Lower Huronian.	
	Unconformity.	
	Laurentian granites, gneisses, etc.	
	Irruptive contact.	
	Keewatin.	Ontarian.
	Coutchiching.	

In the Rainy Lake region the Steeprock series of sediments (including fossiliferous limestone) and volcanics is tentatively correlated with the Lower Huronian. Following an interval of uplift, deformation, and erosion, came the Seine series of sediments, which is tentatively correlated with the Upper Huronian. Dr. Lawson's memoir is of absorbing interest, and will strongly appeal to all those who find a fascination in the more ancient rocks of our aged planet.

ARTHUR HOLMES.

VI.—PRELIMINARY REPORT ON THE SERPENTINE AND ASSOCIATED ROCKS OF SOUTHERN QUEBEC. By JOHN A. DRESSER. Geological Survey of Canada. Memoir No. 22. pp. viii + 103, with 2 folding maps. 1913.

THE serpentine belt consists of a series of basic igneous rocks intrusive through sedimentary rocks of Palæozoic age. Although on account of its economic importance serpentine gave its name to the belt, it is actually the least abundant of the principal rocks of the series. It is of two types, in the one resulting from the alteration of peridotite and in the other of pyroxenite, but both were members of a series of intrusive rocks differentiated from a single magma. The belt includes two minerals of great economic importance—asbestos and chromite. The asbestos, which is mineralogically chrysotile, is of two kinds, one, which is found in veins, being longer, stronger, and more valuable than the other, which occurs parallel to the cleavage of the rock. The mines are by far the largest of the kind ever worked, and provide at the present time about 90 per cent of the world's supply, the annual production amounting to about £500,000. Chromite is shipped mainly to the United States, where it is used in the manufacture of bichromates for use in dyeing textiles and tanning leather, for pigments used in printing and painting, in making chrome steel, and in lower grades for lining furnaces. Among the other minerals found are chalcopyrite, pyrite, stibnite and other antimony minerals, platinum (in minute amount), diamond (in crystals of good quality, but far too tiny for gem purposes), vesuvianite, and magnetite.

VII.—PALÆOZOIC CIRRIPEDES FROM SWEDEN.

OM SVENSKA SILURCIRRIPEDER. Af JOH. CHR. MOBERG. Lunds Universitets Årsskrift, N.F., Afd. 2, Bd. 11, No. 1. Kgl. Fysiografiska Sällskapets Handlingar, N.F., Bd. 26, No. 1. pp. 20, 2 pls. July, 1914.

THIS interesting paper does not deal with *the* Silurian (*sensu lato*) cirripedes of Sweden, but only with some of them, the inception of the work being due to a recent discovery of cirripedes in the Black Trinucleus Shales near Ullnäs in Ostrogothia, which led to a comparison with material that had accumulated from the same beds in Dalecarlia. The three new species described are all from the Black Trinucleus Shales, but figures are also given of a possible *Plumulites* from the Colonus Shales of Scania, a doubtful *Turrilepas* from the Leptæna Limestone of Dalecarlia, and a plate from the Silurian of Gotland assigned to *Turrilepas wrightiana*.

In the course of a brief survey of what has already been published on the Silurian and Ordovician cirripedes of Sweden, the author points out that the name *Pollicipes validus*, which C. W. S. Aurivillius in 1892 applied to a scutum from Gotland, was preoccupied by Steenstrup for a Cretaceous species. For the Gotland fossil he therefore proposes the new name *P. aurivillii*. It may here be remarked, since Professor Moberg has not troubled to do so, that recent work on Cretaceous cirripedes, especially that of Mr. T. H. Withers, shows the high improbability, if not impossibility, of there being in the Silurian any representatives of either *Pollicipes* or *Scalpellum*.

The species described by Professor Moberg are referred to *Lepidocoleus*, *Turrilepas*, and *Plumulites*, and he precedes his description of them with a discussion of those three genera.

For some reason British palæontologists have persisted in regarding *Plumulites* Barrande as a synonym of *Turrilepas* H. Woodward. In both genera the visible plates are arranged in four vertical rows; but, as Professor Moberg points out, in *Turrilepas* these form two principal rows of keeled plates and two outer rows of much smaller unkeeled plates, all of which rows alternate with one another. In *Plumulites*, on the other hand (to which genus Professor Moberg refers the species generally known in this country as *Turrilepas scotica* and *T. peachi*), the so-called dorsal face shows a double row of median plates unkeeled and abutting, not alternating; and on each side is a row of large, kite-shaped plates. It is not easy to describe these fossils in few words, but any one who will compare the figures conveniently brought together on a single plate by Professor Moberg will have no difficulty in appreciating their complete difference of structure.

From both of these genera *Lepidocoleus* Faber differs in being composed of only two vertical rows of plates. Hitherto only three species of this genus have been described, namely, the genotype, originally known as *Plumulites jamesi* Hall & Whitfield, from the Hudson River group of Cincinnati, *Lepidocoleus sarlei* J. M. Clarke, from the Niagara Shales of New York, and *L. polypetalus* J. M. Clarke, from the Lower Helderberg Group of New York. Professor Moberg now introduces a new species, *L. suecicus*, found in Ostrogothia and in various localities in Dalecarlia; he has presented the British Museum with specimens from Ullnäs (regd. I 16018–I 16022), and describes a specimen already in the Museum collected at Svälasgård, Skattungbyn, Dalecarlia (regd. I 14425). Since Professor Moberg says that this is the first species known outside North America, it may be as well to notify the existence of other European species, namely, a large form detected by Mr. Withers among our Wenlock fossils (Brit. Mus. 59058 and 55032), and one from the Middle Devonian near Olmütz, Moravia, submitted to me as a cystid stem in 1912 by Dr. M. Remeš.

Of *L. suecicus* Professor Moberg gives good figures and a detailed description, but excuses himself from a diagnosis or comparison with other species on the ground that previous descriptions are not precise enough. Examination of material in the British Museum from the Trenton, Utica, Lorraine, and Richmond groups of various North American localities, comprising specimens referred to *L. jamesi*, permits one to accept *L. suecicus* as a distinct species. Not only is it actually of greater dimensions, as Professor Moberg says, but the height of the plates relative to their width is greater; and *L. jamesi*, which is perhaps nearest to it in this respect, has the lines of growth more prominent. Professor Moberg has been unable to find in *L. suecicus* "any trace of the peculiar fine sculpture between the growth-lines, which according to Ruedemann characterises *L. jamesi*". The fine striæ at right angles to the growth-lines, ending on them in slight beads, just as described by Ruedemann, are visible in our specimens of *L. suecicus* (I 16020, I 16022). Dr. J. M. Clarke's description of *L. sarlei* and other species (*Amer. Geol.*, vol. xvii, p. 137, 1896) suggests that the plates merely abut on the middle (so-called dorsal) line, and that they alternate; but an excellent specimen from the Trenton group of Minnesota (I 7245), very like *L. sarlei*, shows distinct overlapping with very slight or no alternation.

The mutual relationships of *Lepidocoleus*, *Turrilepas*, and *Plumulites* are still obscure, and the Swedish fossils throw no further light on them. We have indeed still much to learn as to the mere structure of these skeletons before we can so much as say what relations they bore to the rest of the animal. Up to the present the main reason for referring them to the Cirripedia seems to be the difficulty of placing them anywhere else.

On the last page Professor Moberg figures two markings in the Black Trinucleus Shales of Ullnäs, which he believes to represent plates of a Cystid, one of the Rhombifera. His figure 1 certainly supports that interpretation. Since, however, Professor Moberg paid me the compliment of submitting these specimens for my opinion, I am entitled to say that the specimen itself is by no means of such regular appearance, and that neither it nor the original of fig. 2 are accepted by me as echinodermal. My own interpretation, given while still ignorant of the fact that *Plumulites* occurred in these beds, was that fig. 1 might represent one or more kite-shaped plates of that genus. Professor Moberg, however, rejects that interpretation with as much decision as I reject his. And so the matter rests.

F. A. Bather.

VIII.—British Carboniferous *Producti*.

Memoirs of the Geological Survey of England and Wales. Palæontology, vol. i, pt. iv. The British Carboniferous *Producti*. I. Genera *Pustula* and *Overtonia*. By Ivor Thomas, D.Sc., Ph.D. 4to; pp. 168, with 4 plates. London: Dulau & Co., 1914. Price 6*s*.

THE recent great revival of interest in the fauna of the Carboniferous, due to the researches of Vaughan, Sibly, Dixon, and others, has impressed on the author of the present work the necessity for a careful revision of the *Producti*, which form one of the most important groups of fossils in the Carboniferous rocks.

It has been found necessary to give a more detailed differentiation of forms than that which appeared satisfactory to Davidson and de Koninck, and consequently a number of new names have been introduced. The genus *Productus*, which appears to be certainly polyphyletic, has been subdivided into several genera, and the author has endeavoured to restrict the limits of the species and genera in order that these fossils may be used with greater accuracy and precision by both palæontologist and zonal stratigrapher.

In the present memoir only the pustulose and fimbriate forms are described, as the author is most unfortunately unable to complete the work he had undertaken. The introductory sections have, however, been written with a view to the ultimate description of all the British species. One of these sections is devoted to the history of the genus; this is followed by a discussion of the terminology. The terms adopted are in agreement, as closely as possible, with those already generally accepted. Much attention is paid to morphological characters, such as the development and functions of spines, the presence of ribs and costæ, the general shape of the shell, its internal features and shell structure.

Nomenclature and evolution are discussed at some length, though not so fully as had been the author's original intention. The important literature dealing with orthogenesis, homœomorphy, and other problems of evolution is reviewed in a most interesting manner, and copious references are given.

In the section dealing with classification it is proposed to restrict the name *Productus* to that group which contains the original *Anomites productus* of Martin, and to separate the *Producti*, mainly according to the nature of their ornamentation, into the following sections, to each of which is given a distinct generic designation.

Productus, J. Sow. Forms which are costate throughout all stages of growth. Genotype, *Anomites productus*, Martin.

Avonia, gen. nov. Forms which are spinose in the early stages but develop costæ at a later period. Genotype, *Productus youngianus*, Dav.

Pustula, gen. nov. Forms which are essentially spinose in ornamentation. Genotype, *Producta pustulosa*, Phill.

Buxtonia, gen. nov. Forms in which the young and adult stages are characterized by a costate and spinose ornamentation, while in old age spinosity alone is developed. Genotype, *Anomites scabriculus*, Martin.

Overtonia, gen. nov. This genus is founded upon internal peculiarities of the brachial valve, the importance of which is discussed in the definition. Genotype, *Producta fimbriata*, J. de C. Sow.

Proboscidella, Oehlert. Genotype, *Productus proboscideus*, de Verneuil.

Etheridgina, Oehlert. Genotype, *Productus complectens*, R. Etheridge, jun.

The genus *Daviesiella*, Waagen, is not ranked with the above generic divisions, as it is regarded as being more nearly related to the *Chonetes* series.

There are descriptions of twenty-three species of *Pustula*, of which twelve are new, and one species of *Overtonia*.

The work concludes with a comprehensive bibliography and index.

IX.—The Upper Cretaceous and Eocene Floras of South Carolina and Georgia. By E. W. Berry. United States Geological Survey, Professional Paper 84, pp. 200, pls. xxix, 1914.

THE most extensive of the new floras here described is that found in Turonian beds of South Carolina, over seventy species being recognized. Nearly a fifth of these are conifers, and about two-thirds dicotyledons. The facies may be compared with that of the Greenland Cretaceous flora, but there are several cosmopolitan types, and, as in many related floras, there is a mingling of forms such as the willow and walnut with others like the fig, *Eucalyptus* and *Araucaria* which are now climatically separated. The vegetation probably resembled most nearly the 'temperate rain-forests' of to-day, such as those of Southern Japan and New Zealand.

Since the upper Cretaceous deposits of Georgia are marine the plant fossils are fewer than in Carolina, only the most resistant leaves being preserved. Hence speculations on the character of the flora are of little value, but the author thinks that a mild damp climate prevailed.

Some useful maps are given of the past and present distribution of *Cinnamomum*, *Eucalyptus*, and other forms, showing clearly how cosmopolitan Cretaceous types have now become restricted and isolated.

Turning to the middle Eocene plants of Georgia, of which every species is described as new, we find a tropical littoral habitat indicated by several genera which the author has definitely recognized, including a mangrove (*Rhizophora*), which does not now extend so far north.

Many of the figures leave much to be desired, and often represent very fragmentary specimens, even in the case of some of the numerous new species. Regarding the family and generic identification of these leaves, the author himself admits that there is sometimes an element of doubt, and in one extreme case a new species (*Momisia americana*), referred to a genus which "has not previously been recorded in a fossil state", is described from a single incomplete leaf, which, moreover, closely resembles the common genus *Cinnamomum*.

The great difficulties met with in studying fossil angiosperms perhaps accounts for their neglect in England, on which the author comments as follows:—

"The splendid series of plant-bearing horizons of the south of England have, with the exception of sporadic descriptions of certain local florules by De la Harpe, Heer, Ettingshausen, and others, and the work of J. Starkie Gardner on the ferns and conifers, remained unknown down to the present. It seems remarkable that only two Englishmen, Bowerbank and Gardner, have devoted any considerable attention to these floras, and the latter failed to complete his work, so that in many ways the most interesting part of the British Eocene flora, certainly the most useful for purposes of correlation, remains unknown to science except for various antiquated and scattered references."

X.—Resins in Paleozoic Plants and in Coals of High Rank. By David White. United States Geological Survey, Professional Paper 85e, pp. 65–96, pls. ix–xiv, 1914.

THE importance of resins in the formation of Palæozoic coals is shown to be as great as in later periods. The abundance of resinous spores in Carboniferous times is well known, and in petrified material we see that many Carboniferous plants were provided with secretory canals and cells, the residues in which often suggest resins. Certain carbonized fragments of petioles and wood from the Coal-measures of Montana were found to contain abundant needle-like rods, which from their characters and mode of occurrence seem to represent the resinous fillings of longitudinal canals. Minute refractive bodies in coal have been described by Mr. James Lomax and others as resins, while in coal from the upper Mississippi valley the author discovered small lumps of resin which had persisted almost unaltered. The author suggests that though the amount of exuded resin in early times may have been small, it was abundantly stored in canals. That resins have not been more frequently recognized is due to the fact that they have been altered and carbonized, and in this connexion the author describes the resins in various Cretaceous and Tertiary coals, which have been found in all stages of alteration consequent on the change of the coal itself from peats and lignites to the bituminous types.

XI.—The Soils of Russia.

Die Typen der Bodenbildung, ihre Klassifikation und Geographische Verbreitung, von Professor Dr. K. Glinka, Direktor des landwirtsch. Instituts des Kaisers Peter I zu Woronesh. pp. 365, with 65 text-figures and a coloured map. Berlin (Borntraeger), 1914. Price 17*s*.

IT has long been known to workers in agricultural geology that a great amount of most valuable work in soil-investigation is being carried on in Russia. Occasionally portions of this have been made accessible to Western readers, such as the well-known papers of Sibirzev, communicated to the Geological Congress at Petrograd, and some most valuable memoirs submitted to the Agro-geological Congresses at Budapest and Stockholm. But in the case of the greater part of this work publication in the Russian language is an insuperable bar to its wider appreciation. Now, however, it has happily occurred to Professor Glinka to issue a German translation of his Russian lectures, illustrated by many figures and an admirable soil-map of the Russian Empire.

Briefly stated, the general thesis of the Russian soil-investigators is as follows: that the determining factor controlling the character of the soil is climate; under given climatic conditions similar soils can be formed from a great variety of different rocks. This is specially noticeable in the case of the well-known Tchernosem or black earth of Russia, a soil which maintains its fertility without manure for an indefinite time.

The soils of Russia may be divided into zones or belts, which, on the whole, show a close parallelism to the climatic belts, running in a general north-east and south-west direction. In European Russia the zones generally recognized are, beginning in the south-east, the salt-steppes, the dry steppes, the Tchernosem, which may be compared to the prairies of America, the grey and bleached forest soils (podsol zone), and finally the frozen tundras of the far north. Besides these certain minor transitional forms are also recognized. None of the Russian soils appear to be quite similar to the normal meadow soils and 'brown earths' of Western Europe and Eastern America.

In the book before us a full account is given of the origin and characters of each of the principal soil-types of the Russian Empire, the whole subject being treated mainly on a climatic basis. The classification adopted is chiefly founded on the work of Sibirzev and Dokutchaiev, and the book forms a most valuable résumé of recent work of great importance, hitherto inaccessible; it should be carefully studied by all soil-workers in spite of the unnecessarily high price.

R. H. R.

XII.—Coast Sand Dunes, Sand Spits, and Sand Wastes. By Gerald O. Case. pp. xii + 162. London: St. Bride's Press, 1914. Price 5*s.* net.

THE object of this little book is to direct attention to the waste and devastation produced by the inland movement of sand dunes, and to show the beneficial results which follow when inblown sand is allowed to accumulate under human guidance, and fixed by artificial means so as to provide a permanent protection rather than a continual menace to the coast. Sand dunes may be fixed in three ways: (1) by planting a belt of suitable grasses and shrubs just above high-water line; (2) by building an embankment of earth or sand; and (3) by constructing a row, or series of rows, of openwork fencing. In these ways the formation of barren wastes by the inland drifting of sand is prevented, a line of defence against coast erosion is maintained, and it becomes possible to reclaim sand wastes already existing and convert them into pine woods, which are not only more beautiful, but which become, in the course of time, an important commercial asset.

Mr. Case deals adequately with these phases of his subject, not only from the engineering point of view but also from a geological standpoint. A large number of examples are cited, drawn from localities in all parts of the world, a feature which gives the book a special value as a work of reference, but which necessarily detracts from its quality as a readable work. The matter is, however, soundly treated throughout, and can be confidently accepted as an authoritative statement of a subject of extreme economic importance. It should prove to be of great value to coast engineers and local authorities who have to deal with the problem of moving sands. The book is well illustrated with numerous photographs and line drawings. The price appears to be somewhat excessive, and we would suggest that in a later edition the index, which is incomplete in its present form, should be considerably amplified, especially in regard to local place-names.

XIII.—THE VOLCANOES AND ROCKS OF PANTELLERIA. By HENRY S. WASHINGTON. Journal of Geology, vol. xxi, No. 7, p. 653, No. 8, p. 683, 1913; vol. xxii, No. 1, p. 16, 1914.

THE island of Pantelleria[1] lies midway between Sicily and Tunis, and with the exception of some local beds of travertine the exposed rocks which enter into its architecture are wholly volcanic. It is probable that a basement of plutonic rocks underlies the volcanic superstructure, for fragments of granite have been found in the lavas of Pantelleria, and xenoliths of diorite in the lava of Linosa, a small volcanic island which lies to the south-east. Pantelleria has become classic through the researches of Foerstner, who discovered there a remarkable series of lavas containing soda microcline and cossyrite. In 1905 a re-examination of the island was undertaken by Dr. Washington, and the present paper is the outcome of his studies in the field and subsequently in the laboratory.

The volcanic history of the island appears to have been as follows:—

Phase 1.—The building up of a large cone on a granite basement by successive flows of—

(1) Pantelleritic trachyte	. .	66·85 SiO_2.
(2) Comendite	. . . . .	72·21 SiO_2.
(3) Ægirite or green pantellerite	.	71·15 SiO_2.

This phase was ended by the formation of a caldera with its surrounding *somma*, owing either to explosion or to subsidence.

Phase 2.—The building up of a cone within the caldera by flows of—

(4) Soda trachyte	. . . .	63·46 SiO_2.
(5) Pantelleritic pumice	. . .	67·32 SiO_2.

Dislocation of part of the cone then took place, tilting up the south and depressing the north. Through the fractures so produced an eruption then took place of—

(6) Black pantellerite	. . .	69·08 SiO_2.

Phase 3.—At the north-western end of the island eruptions of—

(7) Basalt	. . . . .	46·09 SiO_2

then broke through. A submarine eruption in 1891 near the north-western coast marks the last sign of eruptive activity. Fumaroles (hot steam and sulphur dioxide) and hot springs (rich in soda) are now found in various parts of the island.

An excellent map of the island showing the distribution of the chief varieties of lava is given. Petrographic descriptions follow the general summary of events, and this part of the paper is enriched by seventeen analyses. In the succession of lavas as stated above, the average silica percentage of each member is appended, and it becomes clear that the rocks are sharply divided into two main groups, and that the order of succession agrees well with that enunciated by von Richtofen and Iddings, especially as regards the extreme character of the final product. The acidic lavas are remarkable for the consistent absence of nepheline and soda-lime plagioclase. All the felspars are alkalic, averaging $Or_1 Ab_1$. The remaining soda is to be found in ægirite and cossyrite, and the excess of silica has crystallized as

[1] Note that the main accent is on the *i*, not on the second *e*.

quartz. Titanium, and to a less extent phosphorus, are remarkably abundant, and this feature becomes especially noteworthy in the basalts. It seems to be possible to correlate the presence of cossyrite with the high content of titanium, and the absence of riebeckite with the absence of fluorine and the low proportion of zirconium.

ARTHUR HOLMES.

XIV.—GEOLOGICAL EXCURSIONS ROUND LONDON. By GEORGE MACDONALD DAVIES, B.Sc., F.G.S. pp. 156, with maps, sections, and photographs. Thomas Murby & Co., 1914. Price 3*s*. 6*d*. net.

THIS is a useful little handbook and guide to the geology of some of the most interesting localities in the neighbourhood of London. The book is intended primarily for the use of students who require to gain some knowledge of field geology and who should be able to learn a great deal by following out these carefully planned excursions. It will also, no doubt, appeal to the many who are really interested in the geology of the London district, but are often unable to find their way to important sections or instructive view-points.

The first thirty-four pages are devoted to an outline of the stratigraphical geology of the South-East of England, the arrangement of which is clear and concise.

Twenty-six excursions are planned, fifteen of which are arranged as half-day excursions. Particulars of railway routes and fares are given, and with the very full directions it should be possible to follow out the itinerary without the aid of a map. Teachers should find this book of value in conducting field classes.

XV.—BRIEF NOTICES.

1. ARGYLLSHIRE AND BUTESHIRE. By PETER MACNAIR, F.G.S. pp. x + 161. Cambridge University Press, 1914. 1*s*. 6*d*. net.

The excellence of the Cambridge County Geographies has now been universally recognized, and in this member of the series, one of the latest to be issued, the high standard is easily maintained. The author has in Argyllshire a county which is extraordinarily difficult to describe from the geological and structural point of view in a space so short as that at his disposal. In Buteshire his task is less formidable, but in both cases he has succeeded in writing an admirable account of geological history, and of the surface features, scenery, and economic conditions which are its natural outcome. The book gives a well-balanced and thoroughly interesting account of two fascinating counties which provide holiday centres that are not easily surpassed.

2. NOTES ON RADIUM-BEARING MINERALS. By WYATT MALCOLM. Prospector's Handbook No. 1. Issued by the Geological Survey of Canada, 1914. pp. 26.

In this handy little book the uranium minerals—pitchblende, carnotite, autunite, and torbernite—and the modes of testing their radio-activity by the electroscope, the scintilloscope, and their effect on a photographic plate (the last, as the author warns, resulting also from thorium minerals) are considered, and descriptions given of the more important localities in Portugal, Colorado, Utah, Cornwall, and Bohemia where the ores are commercially worked. The Canadian occurrences are more fully dealt with, and some useful hints are given to help the prospector in his search.

3. Geology of the Pitchblende Ores of Colorado. By Edson S. Bastin. United States Geological Survey, Professional Paper 90, A, 1914. pp. 5.

After a preliminary account of the principal pitchblende-producing localities the occurrence in the Quartz Hill District, Colorado, is considered. From a study of a polished section it appears that pitchblende crystallized contemporaneously with chalcopyrite, pyrite, and probably grey quartz. The predominant rocks are pre-Cambrian igneous and sedimentary rocks and Tertiary intrusive rocks. A lead-zinc mineralization followed closely a pyrite one, and pitchblende was deposited during the latter and afterwards fractured, the fractures being filled by sulphides of later mineralization.

4. Cretaceous Exogyras.—Professional Paper 81, Department of the Interior, United States Geological Survey, 1914, is devoted to the description and illustration of Cretaceous Exogyræ from the Eastern Gulf region and the Carolinas by L. W. Stephenson. They are a remarkably beautiful series of shells, being highly ornamented and unlike anything we have in this country. A general description of the deposits, and a map, prefaces the descriptions.

5. The Jurassic Flora of Cape Lisburne, Alaska. By F. H. Knowlton. United States Geological Survey, Professional Paper 85d, pp. 39–55, pls. v–viii, 1914.

The Corwin formation of Northern Alaska, containing much workable coal, has yielded several fossil plants, which show that the beds belong to the upper part of the Middle Jurassic. The flora is most closely related to that of Eastern Siberia, and of the seventeen species found in the Cape Lisburne region eight occur also in Amurland. The general facies is that of Jurassic floras almost all over the world, and this extraordinarily wide distribution leads the author to consider the possible means of dispersal of Jurassic plants. He concludes that there must have been "a practically continuous land connection between the several localities during Jurassic time", since only the ferns, with their light spores, could have crossed any considerable stretch of water.

6. Kalgoorlie, Western Australia.—Part i of the *Geology and Ore Deposits of Kalgoorlie* was issued in 1912 by Messrs. Simpson and Gibson, and we have lately received the second part by Messrs. Feldtmann & Farquharson,[1] together with the maps of the area. This district is now completed, and its rocks petrographically described. The publications are issued by the Geological Survey of Western Australia, Bulletins 42 and 51, at 5*s.* the two.

[1] An article, by R. A. Farquharson, F.G.S., on the "Petrology of a portion of the North Kalgoorlie Field" (Western Australia), appeared in the Geological Magazine for March, pp. 107–14, and April, pp. 148–57, 1914, Pls. V–VII.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

November 5, 1914.

1. "On Acquired Radio-Activity." By Sir William Crookes, O.M., LL.D., D.Sc., Pres. R.S.

Various objects, diamond, ruby, garnet, quartz, gold, platinum, etc., also the phosphorescent substances yttria, calcium sulphide, zinc blende, and barium platinocyanide, are bombarded in a high vacuum by cathode rays, and in no case can any permanent activity be recognized either by photographic or electrical means.

Exposure to radium emanation confers temporary radio-activity on all bodies that have been tried, apparently due to the condensation of the emanation on the surface. This transient activity can be completely removed by washing in dilute acids.

Many substances become coloured by direct exposure to radium, the colour depending on the substance. Diamond takes a full sage-green tint, the depth of tint depending on the time of exposure to the radium.

In addition to change of colour diamond also becomes persistently radio-active, continuously giving off α-, β-, and γ-rays. The acquired colour and activity withstand the action of powerful chemical agents, and continue for years with apparently undiminished activity.

Removing the surface by mechanical means removes both colour and radio-activity.

The appearance of an auto-radiograph made by placing an active diamond crystal on a sensitive photographic plate, and the visual examination of its 'scintillation' luminosity, suggest that there is a special discharge of energy from the corners and points of the crystal.

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2. Medals for Research.

The King has approved of the following awards this year by the President and Council of the Royal Society:—

A Royal Medal to Professor Ernest W. Brown, F.R.S., for his investigations in astronomy, chiefly in the Lunar Theory.

A Royal Medal to Professor William J. Sollas, F.R.S., for his researches in palæontology, especially in the development of new methods.

The following awards have also been made by the President and Council:—

The Copley Medal to Sir Joseph Thomson, O.M., F.R.S., for his discoveries in physical science.

The Rumford Medal to Lord Rayleigh, O.M., F.R.S., for his numerous researches in optics.

The Davy Medal to Professor William Jackson Pope, F.R.S., for researches on sterochemistry and on the relations between crystalline form and chemical constitution.

The Darwin Medal to Professor Edward B. Poulton, F.R.S., for his researches in heredity.

The Hughes Medal to Professor John S. Townsend, F.R.S., for his researches on electric behaviour of gases.

II.—Geological Society of London.

November 4, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President announced that, at a meeting of the Council held that afternoon, it was decided to allow all Belgian geologists to enjoy the privileges of the Society during their enforced residence in our country. The Officers would be glad of the co-operation of the Fellows in bringing the names of such Belgian geologists to their notice.

The following communications were read:—

1. "The Inferior Oolite and Contiguous Deposits of the Doulting–Milborne Port District (Somerset)." By Linsdall Richardson, F.R.S.E., F.G.S.

In this paper a detailed description is given of the Inferior Oolite and contiguous deposits in the country between the Bath–Doulting and Sherborne districts. It embraces the country around Bruton, Castle Cary, and Blackford.

In the northern half of the Doulting–Milborne Port district the bulk of the yellow Upper Lias Sands is of *dispansi* hemera; but in the neighbourhood of Cole and Castle Cary the very topmost portion is of *dumortieriæ* hemera. In the south-eastern portion, under Stowell, while the main mass is probably of *moorei–dumortieriæ* hemeræ, the upper 50 feet or more is certainly of *aalensis–moorei* date.

Throughout the greater portion of the district the Inferior Oolite is, without doubt, non-sequentially related to the Upper Lias Sands.

Rock of *garantianæ* hemera spreads over the whole district, and is everywhere non-sequentially related to the beds below. From Doulting to the neighbourhood of Bruton the *Garantiana* beds rest directly on the Sands. In the neighbourhood of Cole, however, there is a synclinal area, and beds of *blagdeni*, *sauzei*, *witchelliæ*, *shirbuirniæ*, *discitæ*, and *murchisonæ* hemera are seen between the *Garantiana* beds and the Sands. The lower portion of the *Discites* bed at Strutter's Hill, Cole, is precisely identical, both as regards faunal and lithic characters, with the celebrated 'Fossil Bed' of Bradford Abbas.

None of these deposits seen in the neighbourhood of Cole is met with again until the neighbourhood of Corton Downs is reached. An anticlinal axis runs through the middle of the intervening tract, and is along a well-marked line of weakness.

At Corton Downs are rocks of *sauzei*, *witchelliæ*, *shirbuirniæ*, *discitæ*, *bradfordensis*, and *murchisonæ* hemeræ—that of the first hemera being identical with the "marl with green [glauconite] grains" at the well-known Milborne–Wick section. In this southern portion of the district, as is the case also around Cole, it is very difficult to determine the upper and lower limits of the deposits of *discitæ*, *shirbuirniæ*, and *witchelliæ* hemeræ. They comprise grey sandy limestones with sandy and marly partings—the whole of very uniform aspect and frequently rich in glauconite grains.

The rock of *garantianæ* hemera varies much from place to place in thickness and lithic structure. Near the Mendip Hills it is a conglomerate bed; in the country around Batcombe, ragstone very similar to the Upper *Trigonia* Grit of the Cotteswolds; at Strutter's

Hill, in part an *Astarte obliqua* bed—precisely similar to that at Halfway House and Burton Bradstock; at Hadspen, mainly a massively bedded brown building-stone (locally called 'Hadspen Stone'), full of fossils. Similar rock is seen at Shotwell and Woolston; but south of Blackford the *Garantiana* beds coalesce, as it were, with the superincumbent representative of the Doulting Stone, etc., and, while the lower part eventually passes into the Sherborne Building-stone, the upper portion (together with the equivalents of higher beds) becomes rubbly, associated with clayey matter, and passes into the Rubbly Limestone beds of the Sherborne district.

Above the *Garantiana* beds come, near the Mendips, the massive Doulting Stone, *Anabacia* limestones, and Rubbly Beds. The *Anabacia* limestones soon lose their distinctive lithic characters; but the Doulting Stone spreads over the whole of the Oolitic tract between Doulting, Bruton, and Cole, and is exposed in numerous quarries.

South of Blackford, as already remarked, the equivalent of the Hadspen Stone (*garantianæ*) is not easy to separate from the equivalent of the Doulting Stone, etc. In the southern portion of the district, the lower portion of the equivalent of the Hadspen Stone passes into the Sherborne Building-stone, and the top portion, *plus* higher beds, into the Rubbly Limestone beds such as those that are so well displayed in numerous quarries in the eastern portion of the Sherborne district.

Samples of the soft layers and of the marly matter from the interstices of the more rubbly beds have been examined by Mr. Charles Upton for micro-organisms; but they have proved singularly deficient in such organisms.

2. "Some Inferior Oolite Pectens." By E. Talbot Paris, B.Sc., F.C.S., and Linsdall Richardson, F.R.S.E., F.G.S.

During the course of one of the present authors' (L. R.) fieldwork in connexion with the unravelling of the detailed stratigraphy of the Inferior Oolite of the district between Stonesfield, in Oxfordshire, and Burton Bradstock, in Dorset—which is now completed—a large number of specimens of Lamellibranchs were found. Some of the *Gervilliæ* and *Pernæ* have already been dealt with (Proc. Cotteswold Nat. F.C., vol. xvii, pp. 233–5 and pl. xi, and pp. 237–54 and pls. xxviii–xxix, 1911). The present paper deals with the species of Pectinidæ that have been found during the investigations above mentioned.

Descriptions and illustrations are given of one new species of *Camptonectes*, of two new varieties of *Chlamys articulata* (auctt.), and of two new species of *Velopecten*.

November 18, 1914.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The following communications were read:—

1. "On a Raised Beach on the Southern Coast of Jersey." By Andrew Dunlop, M.D., F.G.S.

Last June Mr. E. F. Guiton drew attention to a raised beach recently exposed on the southern coast of the island. It is on the eastern slope of the ridge between Le Hocq and Pontac, and the section, facing northwards, shows the following succession of beds from above downwards:—

	Thickness in feet	*inches.*
1. Earthy loam, with a layer of rubble	4	0
2. Stiff brownish-red clay	1	0
3. Yellow loamy clay, containing water-worn pebbles and angular fragments	3	4
4. Coarse brown sand	3	6
5. Water-worn pebbles, closely packed in a matrix of coarse brown sand	4	6

The rock beneath is fine red granite. The section is terminated at its western end by sloping rock, and there, between the rock and the lower beds, is a layer of stiff brownish-yellow clay about 2 feet thick, which is continued for a short distance under the bed of pebbles.

The base of the section is about 50 feet above mean sea-level.

The pebbles in both the upper and the lower beds are mostly of the fine red granite of the locality, but there are some of diabase and of quartzite, as well as a few of flint. Flint is, of course, foreign to the island, but there are many flint pebbles on the recent beaches, especially on the north-eastern coast. Flint pebbles have also been found in at least two low-level raised beaches, and flint pebbles and fragments have been noticed in the yellow clay. Pebbles and fragments of Devonian shale have also been found in what appears to be a remaining fragment of a raised beach on the south-western coast.

Colonel Warton recently pointed out a raised beach, not previously noticed, in the railway cutting near the Eastern Railway station. This is also on the south side of the island, not far from the coast.

Its base is about 55 feet above mean sea-level, and it is covered by a thick bed of yellow loamy clay.

2. "On Tachylyte Veins and Assimilation Phenomena in the Granite of Parijs (Orange Free State)." By Professor S. James Shand, D.Sc., F.G.S., Stellenbosch, South Africa.

The district described is the neighbourhood of Parijs Township, which is situated on the Vaal River and lies upon the northern portion of the Vredefort granite-mass.

The so-called 'granite' near Parijs is a red and grey streaky gneiss, often traversed, both parallel to and across the foliation, by veins of red pegmatite; these are of a later period of consolidation than the rest of the rock. The author concludes from field-evidence that the grey facies of the gneiss results from assimilation of the country rock by an ascending magma, while the red facies represents the residual portion of the same magma.

The special interest of the district, however, lies not so much in the granite as in a system of tachylytic veins which everywhere intersects the granitic rocks. These veins range from a fraction of an inch to 2 feet in thickness, but in the thicker veins there are numerous inclusions of the country rock. They are irregular in form, thickness, and direction, and are due to the intrusion of a basic magma which underlay the district. The author describes the microscopic characters of these tachylytes, and comments on their general glassy and cryptocrystalline nature, which he does not regard as a result of chilling, but suspects is dependent upon the viscosity of the basic magma.

He brings forward evidence to prove that the position occupied by the tachylyte is independent of tectonic features, but follows directly from solution and corrosion of the granitic rocks by the basic magma.

III.—Mineralogical Society.

Anniversary Meeting, *November* 10.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Professor W. J. Lewis: Albite; its Crystal Elements, etc. New values of the elements were obtained based upon measurements made on well-developed twinned crystals from Alp Rischuna. Chemical analysis showed them to be very pure albite.—H. Collingridge: The Determination of the Maximum Extinction Angle, Optic Axial Angle, and Birefringence of Monoclinic Pyroxenes in Thin Sections. The method depends on the presence of well-defined twins about 100, and the visibility of an optic axis through one individual. From observations in this individual of the positions of the trace of the optic axial plane and the twin plane, the extinction angle, and the position of the visible optic axis, and in the other the extinction angle and the birefringence, and, if possible, the positions of an optic axis and the trace of the optic axial plane, the requisite determinations may be made.—Professor H. L. Bowman: Note on Calcite from the Chalk at Corfe Castle, Dorset. Good crystals, which occur in veins in the Upper Chalk, are of the pointed habit, the forms being f $(11\bar{1})$ and x $(21\bar{2})$. Interpenetrant rhombohedra twinned about the c axis as in cinnabar are not uncommon.—A. Scott: Barkevikite from Lugar, Ayrshire, and Litharge from Persia. The former occurs in lugarite in prismatic crystals up to 75 mm. in length with mean refractivity 1·690 and very intense pleochroism, c very dark brown, b reddish-brown, a light yellow; in chemical composition it is fairly close to the type mineral from Barkevik. The latter was found at Larshuran, Persia, as a red mica-like crystalline mass; it is biaxial with mean refractivity 1·735, the double refraction being very weak, and contains over 97 per cent of lead oxide, the remainder being copper oxide with a little antimony oxide.—Dr. G. T. Prior: The Meteorites of Uwet, Kota Kota, and Angela; the identity of Angela and La Primitiva. The meteoric iron of Uwet, Southern Nigeria, said by natives to have fallen about ninety years ago, is a hexahedrite of the Braunau type, containing about 6 per cent of nickel. The meteoric stone of Kota Kota, Marimba District, British Central Africa, said by natives to have been seen to fall some years ago, is a chondrite, probably belonging to the crystalline spherulitic group. The meteoritic iron of Angela, near Iquique, Chili, was found in the nitrate beds. It is an ataxite, containing about 4·5 per cent of nickel and enclosing large nodules of schreibersite, and is probably identical with La Primitiva.

The following Officers and Members of Council were elected: President, Dr. A. E. H. Tutton, F.R.S.; Vice-Presidents, Professor

H. L. Bowman, Dr. A. Hutchinson; Treasurer, Sir William P. Beale, Bart., K.C., M.P.; General Secretary, Dr. G. T. Prior, F.R.S.; Foreign Secretary, Professor W. W. Watts, F.R.S.; Editor of the Journal, Mr. L. J. Spencer; Ordinary Members of Council, Mr. F. H. Butler, Mr. J. P. de Castro, Mr. B. Kitto, Professor A. Liversidge, F.R.S., Dr. J. J. Harris Teall, F.R.S., Mr. F. N. Ashcroft, Professor H. Hilton, Mr. A. Russell, Mr. W. Campbell Smith, Dr. J. W. Evans, Dr. F. H. Hatch, Mr. J. A. Howe.

IV.—Liverpool Geological Society.

The second meeting of the Session was held at the Royal Institution, Colquitt Street, Liverpool, on Tuesday, November 10, 1914, W. A. Whitehead, Esq., B.Sc., President, in the chair. A collection of specimens of Triassic sandstone was exhibited from the recent excavations in Brownlow Hill, and ably described by Miss S. E. Morton. Mr. C. H. Cox, B.Sc., Head Master of Upholland Grammar School, read a paper upon "Ordnance Survey Maps, their Meaning and Use", illustrated by a well-selected series of maps comprising the Highlands of Scotland, the English Lake District, West Cheshire, and the North Downs. Messrs. A. Harris and T. A. Jones exhibited a series of lantern slides of natural scenery in illustration of some of the points described in Mr. Cox's address. A cordial vote of thanks was accorded to Mr. Cox for his interesting paper.

V.—Zoological Society of London.

October 27, 1914.—Professor E. A. Minchin, M.A., F.R.S., Vice-President, in the Chair.

Mr. T. H. Withers, F.G.S., described a new Cirripede based on a number of disconnected valves from the Chalk of Hertfordshire. Except for three valves referred to a new species of *Scalpellum* (*sensu lato*), the whole of the material belongs to a remarkable new asymmetrical Cirripede which differs from *Verruca* in the more primitive structure of the valves, in the presence of two lower lateral valves on the rostro-carinal side, and in the absence of interlocking ribs. This species undoubtedly represents the ancestral type from which has arisen the recent group of asymmetrical sessile Cirripedes forming the family Verrucidæ, and in its structure clearly shows its origin from the symmetrical pedunculate Cirripedes of the family Pollicipedidæ. It presents further evidence that the sessile condition was arrived at independently on several different lines of descent during the evolution of the Cirripedia.

OBITUARY.

WILLIAM HILL, V.P.G.S.

Born August 2, 1849. Died November 8, 1914.

The death of William Hill, on November 8, 1914, came as a shock to many of his friends, who had little idea that his cheery countenance hid a mind liable to fits of depression. Born at Hitchin, August 2, 1849, he was educated at Denmark Hill Grammar School, and appears to have entered at an early age into the public life of his native town. He held positions on the Board of Guardians, Local Board, Urban District Council, Hospital Board, Savings Bank, Corn Exchange, Burial Board, etc., and was created County Magistrate in 1895. On all these positions he brought to bear his geological knowledge, greatly to the advantage of his fellow-townsmen.

Mr. Hill was a Vice-President of the Geological Society of London, President of the Geologists' Association (1911–12), and had done a large amount of original work of value in the Cretaceous rocks. But the great geological work of his life was his unselfish devotion to his crippled friend Jukes-Browne. For years Hill spent week after week in the field, noting and surveying county after county and forwarding all the observations to his friend, who wrote them up for the Geological Survey memoir called *The Cretaceous Rocks of Britain*. Further results of this work were his brilliant addresses as President of the Geologists' Association on "Flint and Chert" and "Rocks containing Radiolaria", papers demanding not merely knowledge but technical skill and patience. William Hill died at Hitchin, November 8, 1914, and was buried there.

HENRY JAMES JOHNSTON-LAVIS, F.G.S., Etc.

Born July 19, 1856. Died August 10, 1914.

Dr. Johnston-Lavis was born in London, July 19, 1856. On the close of his primary education at a private school he sought to enter on the medical course at the University of Montpellier. That institution, however, having had to be closed on account of a revolt of the students, he attended instead at the University of Marseilles, where he studied for a year. At the beginning of the session 1873–4 he transferred to University College, Gower Street, London, and also studied some subjects at St. Mary's Hospital, Paddington. At the former institution he was placed in the First Class in Practical Chemistry in 1874, and in the First Class in Clinical Medicine in 1878. While there, also, he came under the teaching of Professor John Morris, then at his zenith, for Geology. This subject strongly attracted him and he joined the Geologists' Association in 1874, and was elected a Fellow of the Geological Society in 1875, having been by an oversight admitted before the full age. His first paper, "On the Triassic Strata which are exposed in the cliff sections near Sidmouth," was read before that Society in the following year. The bones he discovered at that locality proved to be new, and were described at the same time by Professor H. G. Seeley under the name of *Labyrinthodon Lavisii*. In 1876, also, he conducted evening classes in Physiology at the old Polytechnic in Regent Street. For several years he made a careful study of the Lower London Tertiaries exposed at Charlton and at Lewisham, which resulted in a paper attempting a correlation of the two sections, read before the Geologists' Association in 1877.

After obtaining his M.R.C.S.Eng. and L.S.A. in 1878 he married Mlle. Antonia Françoise Bourdariat de Saint-Aupre, whose acquaintance he had formed when at Marseilles, and who, he testifies in the dedication to his last published work, "through a long married life encouraged me in my medical and scientific work, affording me valuable help and appreciation and aiding me to overcome almost insurmountable difficulties."

Having spent some time in 1879 as an assistant to a doctor in Plaistow, and after taking the degree of B.ès Sci. Paris, he went out at the end of the year to Naples. There he practised among the members of the English and American colonies and the visitors, and became Sanitary Director to Sir W. Armstrong's works at Puzzuoli. In 1884 he took the degree of M.D. Naples. His attention when there was early directed to the part played by Edible Mollusca in the dissemination of infectious diseases, a subject to which he recurred later. Above all it was at Naples that he was started on his vulcanological studies. To the young, energetic, and ardent geologist Vesuvius, with its many fascinating problems, was a powerful loadstone, and consequently all his spare time was devoted to its study and survey.

His first important memoir on the subject was laid before the Geological Society in 1884. The paper was a long one and the author not then an acknowledged authority on the subject, so some condensation was insisted on before publication. Unfortunately, in his absence from England this was not too wisely or sympathetically done, and the omission of some portions spoilt the continuity of the work, a fact which involved the author subsequently in much useless discussion. The views embodied in the memoir have, however, been widely accepted on the Continent by competent authorities.

Numerous other papers on subjects connected with Vesuvius and the southern Italian volcanoes flowed from his pen during the succeeding years, including a study of, and monograph on, the great earthquake at Ischia, but his chief and perhaps most important work was the completion under great difficulties of his survey of Vesuvius during 1880–8, and publication in 1891 of the Geological Map in six sheets on the scale of 1 : 10,000. Save for the addition of some lava streams during the eruption of 1906 there is but little to alter in the map to-day.

He became a member of the Società Geologica Italiana in 1889, and during the autumn of that year the Geologists' Association paid a visit to the southern Italian volcanoes, mainly at the instigation of Dr. Lavis, on whom fell the brunt of the conduct of the party.

In 1890 Lavis visited Iceland in company with Dr. Tempest Anderson, and his observations there were published in a paper read before the Scottish (now Royal Scottish) Geographical Society in 1895. Mention may here be also made to the joint paper with Dr. J. W. Gregory on "Eozoonal Structure of the Ejected Blocks of Monte Somma", printed in 1894, in which the authors gave the *coup de grâce* to 'Eozoon'. He was appointed Professor (Pareg.) of Vulcanology in the Royal University of Naples in 1893, but never delivered any lectures.

In 1892 Lavis took up a consultative practice at Harrogate for the summer season and continued this annually till 1897. Quitting Naples in 1894, he practised for one season at Monte Carlo, and then made Beaulieu his headquarters for winter seasons and permanent place of residence. In order to qualify for the exercise of his profession in France he had to go through the medical course again, and he took his M.D. at Lyons in 1895, his thesis being a complete résumé of the part played by Edible Mollusca in the propagation of gastro-intestinal diseases.

His activities, however, were by no means confined to the immediate surroundings of Beaulieu, and he took a leading part in the foundation, mainly by the financial aid of Sir John Blundell Maple, of the Queen Victoria Memorial Hospital at Nice, of which he was senior Consulting Physician.

Becoming the English Consulting Physician to the celebrated Établissement at Vittel (Vosges), France, about 1904, he continued his summer practice there till the present year. On the outbreak of the War he dismissed his patients and started on August 1 to join his invalid wife near Château Thierry (Aisne), thence went on to Paris, and finally journeyed south, intending to reach Beaulieu by a circuitous and safe route. Unfortunately the whole journey from the very start from Vittel was attended by misadventures, which culminated on August 10 in the overset of the motor-car in which they were travelling, near Bourges (Cher). The rest of the party escaped with a shaking, but Lavis himself was pinned beneath the car and killed apparently instantaneously.

Although endowed with seemingly inexhaustible energy, it was still wonderful how much he accomplished without relaxing for a moment the scrupulous and unwearied attention he devoted to his very numerous patients. More than 160 books, memoirs, etc., including many important medical theses and articles, in addition to numerous vulcanological writings, stand to his credit; whilst his latest important memoir was *On the effects of Volcanic Action in the production of Epidemic Diseases in the Animal and Vegetable Creation*, etc. (1914), which gained the Parkin Prize of £100 triennially offered by the Royal College of Physicians of Edinburgh.

A man of wide interests, practical ever, rather than what is known as scholarly, he numbered amongst his other pursuits a wide acquaintanceship with ecclesiastical architecture, and the carved woodwork in the little English Protestant church at Vittel was executed by local workmen from his exceedingly tasteful and in some respects unique designs.

Never a moment seemed wasted by him. The odd minutes were devoted to looking after the fittings and furnishing of his laboratory or of his museum, in examining and cataloguing new accessions to his vulcanological library, or in framing after a method of his own some one or other of the valuable engravings he had acquired relating to his favourite subject.

His loss will be greatly deplored not only by his bereaved family, but also by a very wide circle of friends.

INDEX.

ERRATUM.

ZONE OF *OFFASTER PILULA* (BY R. M. BRYDONE).

The table at p. 511 should read as follows:—

	A. granulatus.	Intermediate forms.	*A. quadratus.*
Chalk of zone of *A. quadratus* whose position can be fixed by reference to the zone of *O. pilula.*	Two in Sussex, 15 feet above zone of *O. pilula.*	—	One in Sussex, 8 feet above zone of *O. pilula.*
Subzone of abundant *O. pilula.*	—	—	Four in Hants. One in Sussex.
Upper part of subzone of *E. scutatus* var. *depressus.*	One in Sussex.	Three in Sussex.	One in Hants.

Note.—Two of the Sussex Belemnites have been found since the Sussex section of the paper went to press.

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