THE

GEOLOGICAL MAGAZINE.

VOL. LVII OF WHOLE SERIES.

JANUARY—DECEMBER, 1920.

THE

GEOLOGICAL MAGAZINE

OR

Monthly Journal of Geology.

WITH WHICH IS INCORPORATED

THE GEOLOGIST.

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.

AND

R. H. RASTALL, M.A., M.INST.M.M., F.G.S.,

UNIVERSITY LECTURER IN ECONOMIC GEOLOGY, CAMBRIDGE.

ASSISTED BY

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HENRY WOODS, M.A., F.R.S.
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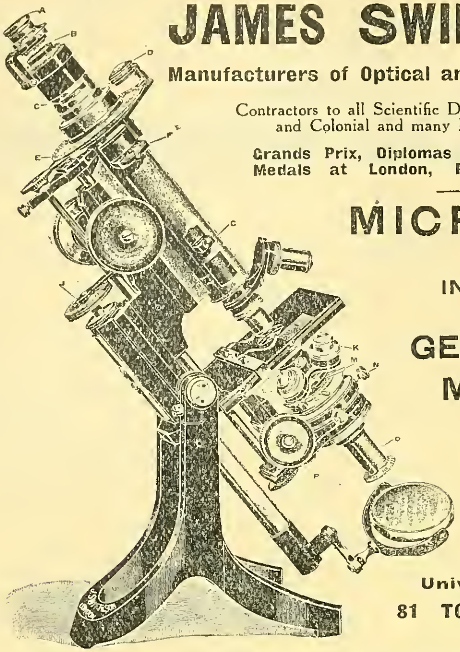
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THE
GEOLOGICAL MAGAZINE

VOLUME LVII.

No. I.—JANUARY, 1920.

EDITORIAL NOTES.

WE must begin the new year by congratulating ourselves that we are alive at all. At one time the outlook was very unpromising, but prospects are now a little brighter, mainly owing to the unremitting exertions of many kind friends, both known and unknown, at home and abroad, to whom the Editors tender their hearty thanks for encouragement and support in a time of need. However, we are not yet out of the wood, and it is obvious that the strictest economy will be necessary for some time to come. It may perhaps be well to point out for the guidance of our contributors some ways in which they can assist in the economy campaign. In the first place the cost of production of plates is now inordinately high, and it may be as well to state definitely that the Magazine cannot afford to publish plates without at least a substantial contribution from the author. We therefore ask our contributors to limit their demands in this respect as much as possible. Again, corrections and alterations in type are now very costly, and much money could be saved if all manuscripts were sent in finally corrected. Occasional printer's errors, though rare in our proofs, are not wholly avoidable, and as to these there is nothing to be said. But it is the alterations of and additions to the text in proof that make the printer's bills mount up. We can assure our readers that with our present circulation the monthly account for corrections is an important item in the balance-sheet.

* * * * *

It may be permissible here to refer to one or two other matters of internal politics. In the first place it will perhaps be noticed that the present number is printed with a new fount of type, and that the titles of papers have been made rather more bold and conspicuous. Again, the former system of numbering the volumes by Series and Decades has disappeared, having been found too cumbrous. The volume for 1919 is numbered alternatively on the title-page Vol. LVI of Whole Series, and the present one is Vol. LVII. In future references in this Magazine to back numbers before 1919 will be given by the year of publication only, without Series or Decade. Most people have their bound volumes lettered simply with the year, and it requires a complicated arithmetical process to discover what is meant by, for example, N.S., Dec. V, Vol. VII. It was our original intention to continue the present system to the end of the Sixth Decade, but on further consideration the bolder course of a clean cut appeared to have much to recommend it, and was finally adopted.

* * * * *

The Non-ferrous Mining Committee continues to hold frequent meetings, and has heard a number of witnesses, who discussed points of interest, especially in connexion with Cornish mining. The general opinion seems to be that in most cases considerable fresh capital is essential for development adequate to meet modern conditions. The outcome, however, depends wholly on the future course of the market for metallic tin. At present prices wolfram appears to be entirely unpayable, and it is regrettable to hear that the very promising Hemerdon mine is closed, after installing new plant on a large scale. The directors appear to be of opinion that the minimum remunerative price is about 55*s.* per unit. At present only one mine is working in the St. Ives district, namely Giew, and that at a loss. It is estimated that to restart the St. Ives Consols group would require an expenditure of £180,000, and it is improbable that so much capital could be raised by private enterprise at this time. Mr. Oliver Wethered expressed the view that the production of the known tinfields of the world could not keep pace with the increasing demand, and was of opinion that high prices for tin would rule for some time to come. With regard to Cornwall, he thought there were possibilities of large production, but considered some immediate help was desirable to stimulate development and to assist in the opening up of new ore-bodies, for the existence of which there is geological evidence.

* * * * *

It has recently been announced that the Geological Survey of Great Britain has been transferred from the Board of Education to the Department of Industrial and Scientific Research; thus this institution undergoes another mutation in its variegated career. In this connexion it may be permissible to point out that the development of our mineral resources is now under the control of no less than five Government departments. The Home Office is in charge of mines in this country; the Mineral Resources Department formed by the Ministry of Munitions has been handed over to the Board of Trade; the Imperial Mineral Resources Bureau collects information with regard to the Dominions and Colonies; the Imperial Institute, which has done admirable work on similar lines, is under the Colonial Office, while, as before stated, the Geological Survey is now under the Department of Industrial and Scientific Research. These facts suggest that there must be an immense amount of overlap and want of correlation in the different branches, and that it is high time that all these scattered departments were welded into a coherent whole under one responsible head. We may be allowed to hope that the institution of a Ministry of Mines will not be long delayed. When this comes to pass it is possible that economic and applied geology will gain some of the recognition which is their due, and that the Government geologists may receive salaries commensurate with their high scientific attainments and with the important character of the work so ably carried out by them.

* * * * *

THE water resources of Queensland obtained by boring are of vast importance to that fertile Australian State, and expert testimony upon the conditions underlying this supply is of great interest not only to those who depend upon them for their means of irrigating the country, but also to engineers engaged in supplying the equipment for this natural resource. An artesian expert writing on the subject says: "My experiences with the bores lead me to the following conclusions, which have been proved correct by boring: When years ago artesian bores were first put down it was the custom to drill a hole an inch larger than the casing, so that the casing would go down easily. This has to be done now. When another layer of casing had to be put in it was just lowered down to where the first lot had struck, and drilling continued. When the flow was struck it came up the casing, and it also came up the space around the casing to the higher sand levels. In time this constant friction of the water made the passage much larger, and in consequence the flow decreased. Now this escaping of the waters to these higher sand levels has done an immense amount of good, as it has put large supplies of subartesian waters where none existed before. I have got the records of artesian bores put down which went through huge dry sand drifts. These bores have a diminished flow, but the sand beds are now full of water, and bores being put down all over them give pumping supplies from 10 to 20 thousand gallons per day at a depth of from 80 to 200 feet. Also from these bores there is no waste, and it is easier and cheaper to put down twenty of them, which will water a larger area of country and will not cost as much money as the one artesian bore."

* * * * *

MR. T. W. READER, F.G.S., has been selected by the Geologists' Association as the first recipient of the Foulerton Award. The sum of money which has enabled the Association to make this award is the recent generous gift of Miss Foulerton, in accordance with the wishes of her late uncle, Dr. John Foulerton, who was for many years secretary to the Association.

ORIGINAL ARTICLES.

On an Inverted Mass of Upper Cretaceous Strata near Leighton Buzzard, Bedfordshire; and on an Overlap of the Upper Gault in that Neighbourhood.

By F. L. Kitchin, M.A., Ph.D., and J. Pringle, F.G.S.

Contents.

1. Introduction.

Mr. G. W. LAMPLUGH and the late Mr. J. F. Walker published a paper in 1903 on a fossiliferous bed at the top of the Lower Greensand, exposed in sand-pits at Shenley Hill, near Leighton Buzzard.[1] The bed in question presented points of considerable lithological interest and was remarkable for its rich brachiopod-fauna. Its position above the "silver-sands" of the Lower Greensand and below a capping of dark "shaly clay", ascribed by those observers to the Lower Gault, led to the conclusion that it belonged to the top part of the Lower Greensand. The discovery of its fossils was considered to throw welcome light on the faunal characters of the latest Lower Cretaceous rocks in England, represented in more southern counties by relatively unfossiliferous sands.

The fauna of this bed of limestone-lenticles raised questions of much interest. While there was apparently an admixture of Lower Cretaceous and Upper Cretaceous species, a considerable number of the fossils present in the bed constituted an association of species known in England only from the lowest part of the *varians* zone, the basal Cenomanian as understood in this country. Such were the large form of *Terebratula biplicata* J. Sow., *T. ovata* J. Sow., *Terebrirostra lyra* (J. Sow.), *Rhynchonella grasiana* d'Orb., and *Rh. dimidiata* (J. Sow.); also the echinoids *Cardiaster latissimus* Ag., *Catopygus columbarius* Lam., *Echinobrissus lacunosus* Goldf., and *Pyrina laevis* Ag. These and other elements of the fauna appeared to contradict the interpretation offered by Messrs. Lamplugh and

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[1] G. W. Lamplugh & J. F Walker. "A Fossiliferous Band at the top of the Lower Greensand near Leighton Buzzard": Quart. Journ. Geol. Soc., vol. lix, 1903, p. 234.

Walker, whose reading of the facts implied an anomaly so arresting as to make further investigation desirable. Nevertheless, those authors were more impressed by the stratigraphical evidence, as understood by them, and remained convinced that the bed occupied a normal position below the Gault. They met the difficulty by explanations which we have always considered to be inadequate,[1] while they treated as so-called " varieties " some of the species which appeared to occur so far below their usual horizon. Arguing from stratigraphical inferences, they claimed to demonstrate that these species in reality made a much earlier appearance and possessed a much longer vertical range than had previously been suspected.

We need make no lengthy comment here on this manner of dealing with the palæontological aspects of the bed ; but we desire to record that from the first we have entirely disagreed with the interpretation given. It has always appeared clear to us that if the bed contains both derived and indigenous fossils its geological age must be that of its latest species. To assume such an early appearance and long persistence for the particular assemblage of brachiopods and echinoids mentioned, has always seemed to us to be making an arbitrary use of the fossil-evidence. Some biological considerations which are in conflict with the assumption need not be entered into here. The zonal significance of these fossils had been firmly established by the well-known facts of their restricted occurrence both in this country and on the Continent. Hence it appeared a hazardous proceeding to ignore the indications they afforded and to place more reliance on stratigraphical appearances.

In subsequent years the above-mentioned authors collected additional fossils from the limestone-lenticles with brachiopods, resulting in further support for our opinion that the true position of the bed is at the base of the Cenomanian. Mr. H. Woods has kindly communicated to us the names of some species represented in the collection obtained by Mr. Walker, now preserved in the Sedgwick Museum, Cambridge. They include the brachyurous crustacean *Cyphonotus incertus* Bell, first described from the so-called " Upper Greensand " of Horningsham, Wiltshire. The type probably came from some exposure in the basal part of the Cenomanian, at which horizon the species is found at other localities in Wiltshire and in Somerset. This fossil also occurs in the Cambridge Greensand. Mr. Woods points out to us that no earlier species of this genus is known. The lamellibranchs at Cambridge include *Pecten* (*Camptonectes*) *curvatus* Geinitz, which occurs in the Upper Greensand of Great Haldon and in the Chloritic Marl, and *Cyprimeria* (*Cyclorisma*) *rotomagensis* (d'Orb.), a species of the basal Cenomanian of Wiltshire. Among the lamellibranchs found in the limestone by Mr. Lamplugh and presented by him to the Geological Survey occurs *Isoarca obesa* (d'Orb.), which is not known elsewhere from below the Chloritic Marl. We have ourselves collected

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[1] Op. cit., pp. 247–9.

Lima globosa J. de C. Sow., the type of which came from the Chloritic Marl. This species has also been recorded from lower horizons, but has not been found below the Gault.

After the publication of the account of the section, Mr. Lamplugh collected some fossils from an inconstant layer of green sand, attaining in one place 5 feet in thickness, found to be intercalated between the limestone-lenticles with brachiopods and the Gault above. The specimens comprised nothing to indicate a Lower Greensand or Lower Gault age, but Mr. Lamplugh was nevertheless inclined to correlate the deposit with the *mammillatus* bed at the base of the Gault.[1] These fossils included well-developed valves of *Ostrea vesicularis* Lam., such as are found in the zone of *Pecten asper* Lam.;[2] also *Ostrea canaliculata* (J. Sow.), a species which occurs much more commonly above the Gault than below it. There were numerous specimens of *Serpula antiquata* J. de C. Sow., a common fossil in the *Pecten asper* zone of Wiltshire. A few associated cirripede-remains were later studied by Mr. T. H. Withers, who kindly furnished us with some notes upon them. He reported that a scutum and a carina must be referred to *Pollicipes glaber* F. A. Roem., and that agreement is closest with specimens from the Chalk Marl. The carina has a narrower base than that of *P. unguis* J. de C. Sow., from the Gault of Folkestone. Another specimen is a scutum which may best be compared with *Pycnolepas rigidus* (J. de C. Sow.), " although it is in some respects rather more advanced in certain characters than the typical valves of that species." *P. rigidus* occurs in the Gault, and Mr. Withers believes that the more advanced evolutionary characters shown by the valves from Shenley Hill indicate a later geological age. He points out that nothing is known from below the Gault with which any of these remains can be compared, and he considers that they furnish evidence that the sand in which they occurred is newer than the Gault.

It is important when considering this disputed question of age to look into the literature dealing with the faunas of the zones just prior to the *mammillatus* bed, as developed on the Continent; that is to say, the *Belemnites strombecki* beds in Brunswick (with the zone of *Leymeriella tardefurcata* at the top) and the Clansayes zone of South-Eastern France. It becomes more than ever clear that the life of that time resembles in no manner that of the brachiopod-bed at Shenley Hill, supposed to be of comparable age. Indeed, this bed furnishes such strong faunal links with the " Cornstones " of Wiltshire and contiguous strata[3] as, in our opinion, to leave no

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[1] " Excursion to Leighton Buzzard": Proc. Geol. Assoc., vol. xx, pt. vi, 1908, p. 475.

[2] H. Woods, *Monograph of the Cretaceous Lamellibranchia of England*, Pal. Soc., vol. ii, pt ix, 1913, figs. 143–5, p. 367.

[3] A. J. Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. ii, " The Lower and Middle Chalk of England " (Mem. Geol. Surv.), 1903, p. 148. A. J. Jukes-Browne & J. Scanes, " The Upper Greensand and Chloritic Marl of Mere and Maiden Bradley, in Wiltshire " : Quart. Journ. Geol. Soc., vol. lvii,

room for doubt. It is in the bed below the "Cornstones" that ammonites of the *varians* fauna first begin to make their appearance. The lenticles of brachiopod-limestone at Shenley Hill may be correlated most appropriately with the basal Cenomanian, which Jukes-Browne tabulated as the sub-zone of *Catopygus columbarius*. No other construction can be placed on the combined testimony of associated species representing four animal-classes.

We need press the palæontological argument no further. There is a corroborative circumstance of much interest. The lithological constitution of the limestone-lenticles, so well described by Mr. Lamplugh,[1] is of a peculiar and distinctive type not matched elsewhere in this country, so far as we know. But the basement-bed of the Chalk (*varians* zone) at Matringhem, Northern France, shows a remarkable similarity of characters. Although samples of the rock from Shenley are as a rule distinguishable by their ferruginous staining, the resulting difference is merely of a superficial kind; and it is possible to select specimens which are inseparable from examples of the Matringhem bed except by the aid of their labels.

In the year 1918 a review of all these considerations served to confirm our previous opinion that an error had been committed; and since Mr. Lamplugh's reading of the section had been accepted by other experienced geologists who had visited the locality, we concluded that the stratigraphical aspect of the series exposed at Shenley Hill must be of a most deceptive character. In the hope of securing data upon which to base a sound interpretation of the succession, we examined the ground in October, 1918, and collected fossils, first of all from the supposed Lower Gault overlying the brachiopod-bed. Since then we have paid numerous visits to the district and have searched for fuller information bearing on the question at issue.

A consideration of the stratigraphical, lithological, and palæontological evidence thus obtained has led to the conclusion that in the sections at Shenley Hill where the masses of brachiopod-limestone have been found, these lenticles, the inconstant layer of green sand above them and the overlying Gault Clay, are in an inverted order of succession. The overturned mass of strata does not in itself form a complete unbroken series. There is definite evidence of one non-sequence within it, and there may be a second one. We are also able to show that the strata upon which the inverted beds now repose do not constitute a simple conformable series. The top of the Lower Greensand is here overlain unconformably by the basal bed of the Upper Gault, which in the neighbourhood of Shenley Hill lies transgressively upon older strata.

1901, p. 96. J. Scanes, in Report by B. Pope Bartlett & J. Scanes, "Excursion to Mere and Maiden Bradley, in Wiltshire": Proc. Geol. Assoc., vol. xxvii, pt. iii, 1916, pp. 122–5.

[1] Op. cit., pp. 241–2.

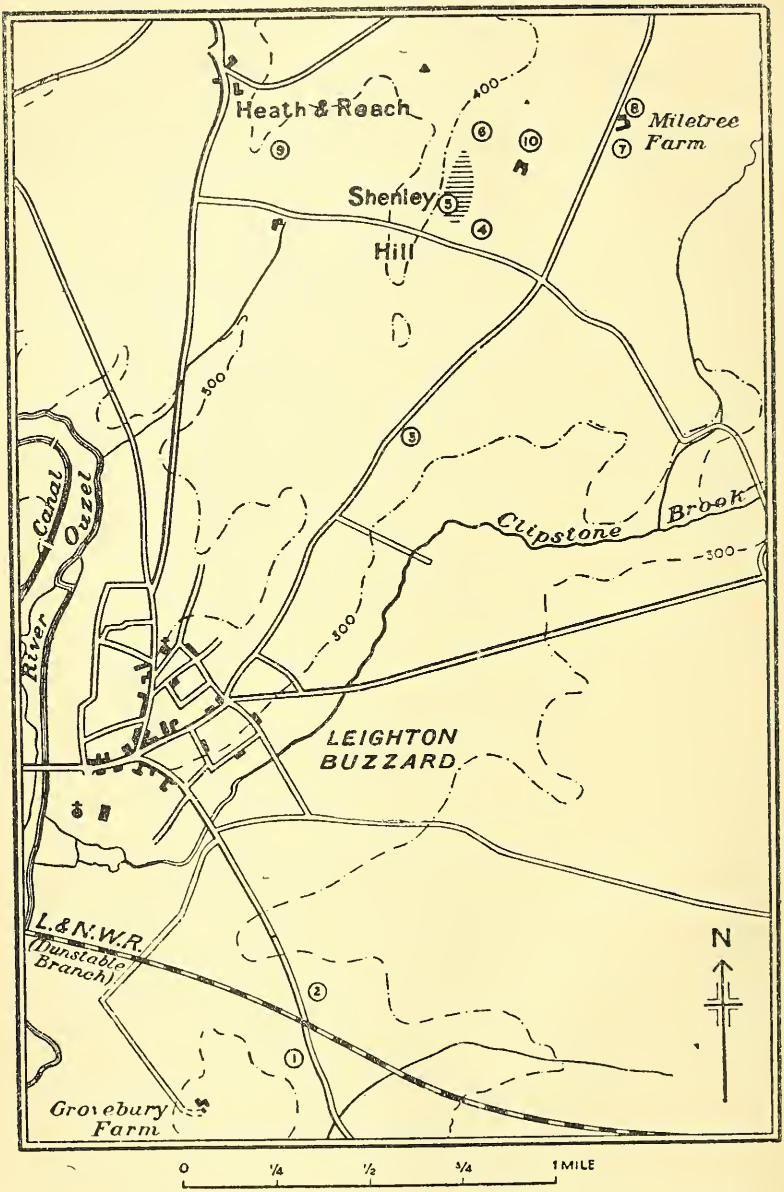

Fig. 1.—Sketch-map to show the positions of the sections described. The map is adapted from the 1 in. Ordnance Survey map. The numbers indicate the position of localities referred to in the text. The shaded patch at locality No. 5 represents the estimated former extension of the inverted mass of strata in worked-out areas in the sand-pits.

2. The Section.

The only section showing all the above relationships at the present time is that exposed in the sand-pit of Mr. Gregory Harris (No. 5),[1] to whose kindness we are indebted for permission to collect at that locality. The main features of this striking exposure have been described by Mr. Lamplugh, whose account of the strata may be summarized as follows, from his description of the succession seen at the northern end of the pit (op. cit., Fig. 3, p. 238).

In descending order, below 1 foot of soil :—

A.	Bluish-grey Boulder-clay	2–6 feet.
B.	Gault : bluish-grey shaly clay above, dark-blue below	4–7 feet.
C.	Irregular band of iron-grit	1–3 inches.
D.	Ochreous or greenish-yellow loamy sand, grit, and breccia ; replaced here and there by lenticles of pale flesh-coloured or yellowish gritty limestone, full of fossils [the brachiopod-bed]	1–2 feet.
E.	Undulating iron-grit band	2–3 inches.
F.	Greyish loamy greensand, with clayey streaks and lenticles of pebbly grit	2–3 feet.
G.	Lenticles of dark-red and ochreous iron-grit, with small included nodules of sandy pyritous claystone ; streaks of fuller's earth, dark clayey greensand, and ochreous loam below ; forming a well-defined band capping the "silver-sands"	1–1½ feet.
H.	"Silver-sands," strongly cross-bedded	10–15 ft. seen.

Mr. Lamplugh gave a full account of the lithological characters of beds D and H, which, with the intervening strata, he ascribed to the Lower Greensand. He also dealt at some length with the bands, described by him as "iron-grit", C and E. The section as exposed in October, 1918, was substantially the same as in 1903, though during the working back of the pit into the slope of the hill the thickness of the Gault had increased to about 10 feet. The Boulder-clay on the other hand had become reduced in thickness. Early in 1919 an extensive mass of Gault Clay slipped down into the pit and obliterated the whole exposure ; but during the past summer the work of re-excavation has proceeded rapidly, so that the section can again be studied at the southern end of the pit. A result of the slip was to render the Gault accessible for examination up to about 18 feet from its base, where it now shows a capping of Drift so inconsiderable as to be scarcely distinguishable from the soil.

A first glance at the section shows an apparent continuity within the series of beds situated above the "silver-sands" and below the Drift. These strata are separated from the cross-bedded sands below by a well-marked plane of division, having the appearance of an unconformity. Mr. Lamplugh drew attention to this line of demarcation, but ascribed to it a minor importance. He wrote : "This line of junction seems to form a definite floor and to imply some degree of erosion and unconformity. Yet in a mass so

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[1] The numbers thus quoted in parentheses are the reference numbers showing the position of localities on the sketch-map, Fig. 1.

irregularly bedded as the Lower Greensand such appearances are not unusual and need not necessarily denote anything more than local erosion and rearrangement."[1] We believe this suggested interpretation of the break to be correct.

Continued excavation during the period covering our visits has shown much variability in the character and thickness of beds D, F, and G. Bed F may be absent, and G may become locally

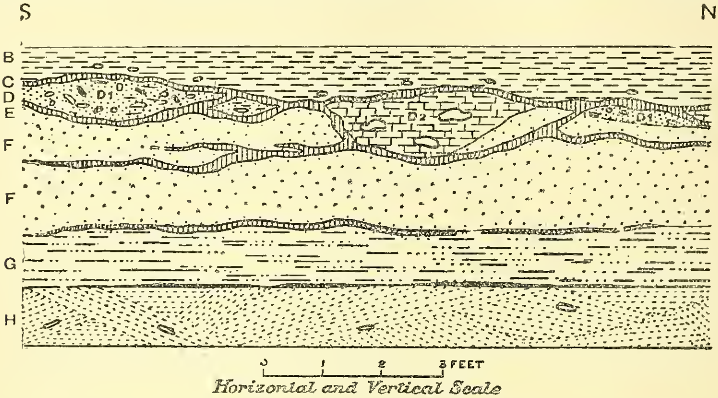

Fig. 2.—Diagram to illustrate a part of the beds seen in the working-face of Harris's Pit, Shenley Hill.

The representation is given in simplest diagram form. It reproduces a part of the section actually seen, where the relations of the beds D and F are less confused than is frequently the case. The clayey sand F is present here in fuller development than in other parts of the section exposed at the same time, where the inverted Gault Clay approached closer to the top of the "silver-sands" and the material of bed D_1 was more continuous and was in places in contact with the sand-bed G.

The letters are those used by Mr. Lamplugh to distinguish the successive beds. The lenticular masses of Mr. Lamplugh's bed D are here marked D_1 and D_2 for the purpose of distinction. According to the reading of the evidence adopted in this paper the age and relations of the strata are as follows:—

B. Inverted top part of the Upper Gault of the neighbourhood. Only a portion of the inverted mass is shown.

C and E. Irregular bands of limonite-ironstone, developed along the surfaces of stratigraphical discontinuity and those of more ready permeability caused by disturbance of the strata. Where the topmost band separates the Gault from the limestone-lenticle D_2 it occupies a surface of non-sequence.

D_1. Remnants of the basal bed of the Upper Gault in situ, resting unconformably upon the Lower Greensand.

D_2. Inverted lenticular limestone-mass with brachiopods, a remnant of the basal bed of the Cenomanian stage formerly present in the neighbourhood.

F. Imperfectly bedded clayey sand of the Lower Greensand, of pre-*tardefurcata* age.

G. Well-bedded fine sand with thin lenticles of carbonaceous clay and lignite at the base: Lower Greensand

H. False-bedded "silver-sand" of the Lower Greensand; only the upper part shown.

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[1] Op. cit., 1903, p. 239.

reduced to a few inches in thickness, while the two may be observed to swell out, only a few yards away, to a thickness of fully 4 feet. The appearance of inconstancy in the strata between the "silver-sands" and the Gault Clay is increased by the lenticular character of the variable masses forming bed D, present in one part of the section while absent in another. (See Fig. 2.)

We have never seen the "dark-red and ochreous iron-grit" in bed G, described by Mr. Lamplugh as occurring in lenticles. Whenever examined by us bed G has consisted of horizontally bedded grey, black- and green-streaked carbonaceous and clayey sand in thin layers, with purer streaks showing a closer approach to the character of the underlying silver-sand, from which the sandy constituents of the bed have apparently been derived. The sand of this bed, particularly in some of the layers, is of an exceptionally fine, smooth texture. At the base, immediately overlying the "silver-sands", there are local patches of carbonaceous clay with much lignite. These are about 2 inches in greatest thickness and may attain a length of 5 feet. We have obtained flat pieces of lignite up to 6 inches in length from this basal layer of bed G. An inconstant seam of limonite-ironstone, varying from 1 to 2 inches in thickness, is present at the junction of beds G and F. It occurs in the form of isolated lenticles varying from 2 to 9 feet in length.

The thin ironstone-bands (C and E), following an undulating course above and below the lenticular masses of bed D, display much irregularity. Mr. Lamplugh has described how they sometimes approach one another, so that they almost meet. We have seen them again and again enveloping the lenticles of limestone and brecciated material of bed D and becoming actually confluent. The lenticular enclosures thus formed may occasionally include a little of the sand of bed F. We have noticed also that the lower ironstone-band, E, frequently gives off branches which pass down obliquely into bed F, and sometimes become joined to a thinner inconstant layer of similar ironstone which occurs here and there with almost horizontal disposition within that bed (see Fig. 2). From these relations we conclude that the bands of ironstone form no original part of the beds with which they are now incorporated, but are of subsequent development. As will presently be shown, no other conclusion is possible in view of the fact that beds D and F are not in normal sequence and are of widely different age. The nature of bed D alone is such as to disprove the contemporaneous origin of the ironstone-bands. The bands themselves, occupying a position along the surfaces of more ready permeability, are composed of limonite, somewhat cavernous in places, with a varying amount of included sand. Where they occur within a sand, as in bed F, they may contain much of the same material. A specimen taken from between a limestone-lenticle of bed D and the Gault Clay above, contains scattered sand-grains no more numerous than the grains within the limestone, which the limonite has partly replaced. But the purity of the limonite varies much, even within the sandy strata. We do not consider that Mr. Lamplugh's term "iron-grit", as applied to these bands, is quite happily chosen.

Bed D, which contains the lenticles of brachiopod-limestone, is of a complex character; it may be more conveniently discussed on a later page in the light of information obtained at other sections. Its confused aspect is the result of a remarkable collocation of heterochronous elements. While the lenticles of brachiopod-limestone belong to the basal bed of the Chalk, there are other lenticles of sandy clay, often with rounded grit-grains and pebbles, which contain angular or subangular fragments and rounded pebbles of ironstone; these masses, together with some patches and streaks of yellowish sandy and earthy-looking clay, are remnants of the basal bed of the Upper Gault. The separate lenticles of diverse origin and age are brought into juxtaposition in such a manner as to appear as if they had originally occupied the same general plane below the base of the Gault Clay in this section; and they have acquired a certain spurious resemblance to one another as a result of secondary ferruginous staining.

Other points must be noted here, the significance of which will appear in our further discussion of this composite bed. In the lenticles and streaks belonging to the base of the Upper Gault we have seen occasional small white calcareous nodules. In one of these irregular streaks we found a flat pale-brown claystone nodule, the source of which, in a stratum of pre-*interruptus* age, can be traced in another section. The lowest two or three inches of the Gault Clay, in contact with the limonite-sheet overlying bed D, are in some parts shaly and fissile in the horizontal direction, and are stained to a reddish hue.

3. THE NEW EVIDENCE.

Neighbouring exposures, where the lenticles of brachiopod-limestone are absent, reveal varying stratigraphical relationships which have an important bearing on the interpretation of the section at Harris's Pit. The Gault Clay in these other sections, when present, is not the same Gault, either lithologically or palæontologically, as that forming the 18 ft. mass above the brachiopod-bed in Harris's Pit. Indeed, the clay and the brachiopod-limestone of bed D in that section are quite local and narrowly circumscribed in their occurrence, a point which we shall presently emphasize. We soon recognized that an important break in the succession occurs there below the brachiopod-limestone.

The fossiliferous limestone-lenticles, which had already received so much attention, seemed to speak for themselves and to require no further palæontological study; hence it appeared advisable in the first place to examine the credentials of the supposed Lower Gault above. Fossils were collected from it at successive levels, and a comparison was made with the Gault seen in normal position above the Lower Greensand in pits near Leighton Buzzard, and also in pits adjacent to Harris's at Shenley Hill, as well as in others further away to the east and west of the hill. The study of these sections enabled us, at the same time, to identify the beds between the "silver-sand" and the brachiopod-limestone at Harris's Pit. Finally, information was sought as to the succession of beds between the Gault and the Chalk Marl along the base of the Chalk escarpment, some miles to the east and south-east.

A. CHARACTERS AND CORRELATION OF THE GAULT IN MR. GREGORY HARRIS'S PIT.

It is a matter of surprise to us that this clay has ever been mistaken for Lower Gault. Its lowest part shows a pronounced marly character, and differs from the true Lower Gault of the district by the absence of sand and the rarity of glauconite; it yields none of the ammonites of the Lower Gault, but contains species characteristic of the *rostratus* zone.

To confine attention first of all to the lowest 8 feet. The well-bedded rock above the lowest few inches has a blocky or sub-conchoidal fracture; it is of a very dark-greenish grey hue when wet, but dries to a much paler colour. Though strongly argillaceous, it contains a considerable proportion of carbonate of lime and it shows minute glistening specks, which at first suggest that it is somewhat micaceous. This appearance is due to tiny flakes of carbonate of lime, probably derived from the thin friable shells of a species of *Anomia*.

With the exception of *Belemnites minimus* List., which is found fairly abundantly a short distance above the base, fossils are not easily obtainable in a state fit for identification. *Inoceramus* is not uncommon, and there are apparently at least two species, one of which is a flattened expanded form suggestive of *I. crippsi* Mantell. Neither *I. concentricus* Park. nor *I. sulcatus* Park. has been found in the lowest 8 feet, although prolonged searches have been made. The presence of small impressions of the characteristically ornamented *Nautilus deslongchampsianus*, d'Orb., indicates a position in the *rostratus* zone or higher. This species has been recorded from the Upper Greensand of Wiltshire (*rostratus* beds and *Pecten asper* beds), but it is more distinctive of the Chalk Marl. Ammonites occur in a band which, in different parts of the section, varies in position from 2 feet to about 4 feet above the base of the clay. They are poorly preserved, in a compressed condition, often consisting of little more than brownish rusty films on the bedding-surfaces; nevertheless, many show plainly the main features. The commonest form is closely comparable with well-known specimens from the sandstones (*rostratus* zone) of the Upper Greensand of Devizes and of the Undercliff, Isle of Wight, variously named in museum collections as *Hoplites auritus* (J. Sow.), *H. catillus* (J. de C. Sow.), or *H. auritus* var. *catillus*.

These well-known ammonites have not been adequately studied, and their relationships remain to be ascertained. They are discoid in form, and are characterized by strongly curved ribs and the loss of these ornaments in the later growth-stages, during which, however, traces of the flattened, swollen rib-endings on either side of the smooth, narrow peripheral area continue to be shown. The naming of these distinctive forms is of little importance in the present connexion; it is sufficient to say that they are members of an easily recognizable hoplitid group which have reached an evolutionary stage characterized by degeneration of the sculptural features. The significant point is that they give us an important datum-line. A specimen of one of them from the Upper Greensand near Devizes has been kindly examined for us by Dr. B. Pope Bartlett, who, after discussing the matter with Mr. J. Scanes, has expressed the opinion that it came from a position about 60 to 80 feet below the base of the Cenomanian stage. This is in the *rostratus* zone, and the similar specimens from the Isle of Wight came from the sandstones underlying the Chert Beds on a corresponding horizon.

Among other fossils found in the lower part of the clay at the locality we are discussing are *Nucula pectinata* J. Sow., *Pecten* (*Syncyclonema*) *orbicularis* J. Sow., and "*Scalaria*" *dupiniana* d'Orb.; but these are valueless in settling the question of age, since their range extends up from the Gault into and above the zone of *Pecten asper*. At about 8 to 10 feet above the base of the clay further ammonites were found. These include a *Hoplites* of the *tuberculatus* group, and another well-tuberculated species showing smooth late growth-stages; also a large involute hoplitid of flattened discoid form, devoid of ornamentation and with narrow concave peripheral area. This appears to represent an advanced evolutionary stage in one of the several series whose members are commonly united under the favourite collective name *H. splendens*. At this level and in the overlying part of the clay there occur large crushed examples of *Inoceramus sulcatus*, Park., a fact of much significance. At about 15 to 17 feet above the base these *Inocerami* are associated with numerous ammonites, including an undescribed *Schloenbachia*, characteristic of the *rostratus* beds, *Schloenbachia varicosa* (J. de C. Sow.) [= *Hysteroceras* of Hyatt], and several species of *Mortoniceras* (the keeled ammonites of the *rostratus* group, *sensu lato*), including at least one belonging to the narrower group of *M. inflatum* (J. Sow.). This association of forms, particularly the abundance of *Inoceramus sulcatus* and *Schloenbachia varicosa*, points to a position in the *rostratus* zone corresponding with Price's Bed IX at Folkestone.[1] This upper part of the clay is rather more limy, and on drying becomes paler in colour than the lower part. The fact that the Upper Gault along parts of the Bedfordshire outcrop shows resemblance to the Chalk Marl has been frequently commented on.

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[1] F. G. Hilton Price, *A Monograph of the Gault*, London, 1880, p. 20. "On the Gault of Folkestone": Quart. Journ. Geol. Soc., vol. xxx, 1874, p. 351.

From the above observations it is seen that no part of the Gault in this pit can be placed lower than the *rostratus* beds. The character and distribution of the fossils lead us to conclude that the upper part of the clay belongs to a lower zonal level than the lower part. Elsewhere *Inoceramus sulcatus* and *Schloenbachia varicosa* are common in the lower part of the *rostratus* beds, absent in the higher part. At Harris's Pit these relations are reversed. If the absence of these fossils from the lower beds there might be thought to indicate that these strata represent the Lower Gault, this is contradicted by the positive evidence of the fossils present and by the absence of any characteristic Lower Gault species. Bearing in mind that the brachiopod-bed, which here underlies the Gault, contains a fauna characteristic of a still later geological date, the facts already set forth seem explicable only on the assumption that the series here exposed is in an inverted position.

It must be noted that the zonally highest Gault seen in this section, that is to say the lowest part of the inverted mass of Gault, is not of sufficiently late age to be succeeded immediately by the basal bed of the Cenomanian stage in a series where there is no zonal break. There is evidently a chronological gap and stratal non-sequence of some magnitude between the clay and the brachiopod-limestone of bed D. The bed of green sand sometimes intercalated between these strata, once seen by Mr. Lamplugh in the contiguous Garside's Pit, provides evidence of the former existence of the connecting deposits. Its faunal and lithological characters, as well as its position, can leave little doubt in our minds that it belongs to the zone of *Pecten asper*, which may have had ample representation here prior to the period of erosion marked by the basal Cenomanian bed. We have never had the good fortune to see any of this greensand in the present section. It appears, however, to have been met with many years ago in Harris's Pit, when the working-face was situated farther to the east, as well as in Garside's Pit, where it was laid bare between the years 1904 and 1906. The junction between the Gault Clay and the intermediate remnant of the Upper Greensand may itself form a line of earlier non-sequence than that shown by the direct contact between the clay and the basal Cenomanian bed. On this point, however, there is at present no conclusive evidence. The facts as we have sketched them provide a simple explanation of the relations between Gault and basal Cenomanian in this section, and one which is wholly in accord with the established principles of zonal determination and correlation. We shall now show that this reading of the evidence obtained at Harris's Pit is amply supported by a comparison with other sections.

(*To be continued.*)

Pre-Triassic Swallow-holes in the Haematite District of Furness, Lancs: a Glimpse of an Ancient Landscape.

By Bernard Smith, M.A., F.G.S.

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A POINT of economic importance, as well as scientific interest, has been brought out by a study of the occurrences of hæmatite in the Furness district of Lancashire and the neighbouring shores of the River Duddon in the Millom district of Cumberland; namely, that the origin and distribution of the ore-bodies, known as "sops", is due, in large measure, to the physiographical conditions that existed in this area in post-Carboniferous but pre-New Red times. Future explorations for these profitable ore-bodies may be guided by a true appreciation of the conditions of formation, which are discussed, in somewhat scattered form, in the recently published Geological Survey Memoir [1] on the "Hæmatites of West Cumberland, Lancashire, and the Lake District".

The following is a more connected resumé of the events that gave rise to the sops and the reasons for their restricted occurrence.

We may preface our remarks by stating that (1) the hæmatite found in the Carboniferous Limestone, both in Cumberland and Furness, is due to a metasomatic alteration of the Limestone, presumably by the descent of iron-bearing solutions stored in the New Red beds that overspread the Carboniferous rocks; and (2) "sops" may be defined as bodies of ore, circular to oval in form, and narrowing downwards irregularly like deep basins or pockets in limestone.

It appears that in pre-New Red times the main mass of Carboniferous Limestone formed a widespread plateau extending from near Kirksanton, north-west of Millom in Cumberland, eastward to near Lindal-in-Furness, and was dominated on the south by a northward-facing escarpment of Yoredale Beds. South-west of Dalton-in-Furness the escarpment looped southward to near Yarlside and Stank, as a sharp V-shaped notch, the eastern wall of which was a pre-New Red fault-scarp trending from north to south.

At the present day swallow-holes and caverns are abundant on such limestone plateaux, and as fast as the swallows go out of commission, or the cavern-roofs collapse, they become choked with débris, mostly of an angular and open character, and occasionally roofed with turf. So also in this case swallows were formed, and when a hole ceased to serve as an open conduit, material falling from the walls filled the bottom with coarse limestone débris, and included masses of limestone-shales. Disintegrated shale and mud, washed in, formed a rough lining to the whole mass, and in some cases formed a clayey plug at the bottom. The foot of the escarpment, also, became the depository of screes or brockrams as

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[1] Special Reports on the Mineral Resources of Great Britain, vol. viii, 1919.

the escarpment slowly receded under the action of weathering agents.

In New Red times both the plateau and escarpment were overspread by characteristic deposits of dolomitic limestone and breccias (both local), red sands, clays, and shales, relics of which still survive in several places, even where there has been great denudation. In the Newton and Yarlside Mine, in the V-shaped notch above mentioned, the old pre-Triassic fault-escarpment has the irregular outline of a present-day limestone cliff, with the New Red Sandstone still banked against it.

At some post-Triassic date the area was upheaved, faulted, and subjected to denudation.

Since the uplift the Yoredale Beds have been worn back by erosion almost 2 miles to their present position near Adgarley and Little Urswick. Farther south they have retreated less. Towards the Duddon shores they are faulted down beneath New Red Sandstone and do not appear at the surface.

The uplift further resulted in the downward movement of iron-bearing waters, which attacked the limestone-breccias in the swallows and caverns, or the limestone along faults and joints.

The mineralizing solutions, entering from above, were concentrated chiefly upon the limestone-breccias, which by nature are peculiarly vulnerable. As the alteration of the limestone fragments progressed the masses of newly formed ore packed together and led to the collapse of the roof and let in the overlying New Red sands and loams in jumbled masses. This episode is recorded in the irregular pockets of such material that are found in the ore of the Park and Roanhead Mines.[1]

That the above is probably the true story receives confirmation from the following facts : (i) After removal of the ore the limestone walls, in some cases, show a smoothing that is characteristic of the action of water, and presumably was effected before the ore was formed. (ii) The sops are lined with "hunger" and "muck". The former is partly composed of weathered shale like that interbedded with the limestone, while the "muck" is probably derived from the ore itself. (iii) Patches of limestone shales are found embedded sporadically in the pure ore. (iv) The ore in the centre of each sop is good soft pick-ore, in small fragments, just such as would be formed from a loose breccia that packed together during alteration. (v) Lastly, a mass at least 122 feet in thickness near its centre, composed of *chocolate-coloured clay like a cave earth*, and containing many subangular waterworn fragments of limestone, has been found recently, filling the bottom of the Nigel Pit sop at Roanhead, *beneath the main mass of ore*. It also contains small sandstone fragments and patches of hunger and muck.

In Furness, therefore, the area in which "sops" may be expected

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[1] Summary of Progress for 1916 : Mem. Geol. Surv., 1917, pp. 9–10.

to occur is constituted by the limestone-plateau, some 7 to 8 square miles in extent, north of the old Yoredale escarpment.[1] To the south and east of the escarpment the ore occurs usually only in vein-like form, and the existence of large bodies of ore becomes less probable with increased distance from the escarpment and a correspondingly increased thickness of cover of Yoredale Beds, which acted as a screen between the iron-bearing solutions and the limestone.

Ore in sop-like form is also likely to occur in the Limestone beneath the Duddon Sands north of Sandscale, and to a less extent perhaps in the Millom area north of Haverigg.

In the sop area (excluding the Duddon shores, where exploration is proceeding) the ore-bodies usually come up to the surface, or to the base of the Glacial drift, and presumably most of these (somewhere near 100) have been located. Some, however, may have remained undetected in the belt where both sops and "veins" occur most freely—i.e. on the line of the foot of the old Yoredale escarpment from the south-east of Dalton as far as the Lindal–Whinfield district. Moreover, some of the old mines might pay to reopen, for they were abandoned owing to trouble with water or poor demand for ore.

In the area where the vein-like ore-body is predominant, south and east of the old escarpment, deep cross-cuts may prove reserves, as in one case where not only is an old vein being worked in depth but new ore-bodies have been discovered.

Brachiopod Nomenclature: The Genotype of *Spirifer*

By S. S. Buckman.

In this Magazine, August, 1919, p. 371, Dr. J. Allan Thomson has an article on the above subject, in which he appears to be expressing the hope that *Spirifer cuspidatus* may not be taken as the genotype of *Spirifer*, though he thinks that certain rules of zoological nomenclature drive him to that conclusion.

It is all very well for zoologists to draw up rules with regard to nomenclature, but they can get tied up with them; and then fresh rules must be made to interpret the former, which may go on *ad infinitum*. Nowadays in science as in politics we are hung up with too many rules. Rules breed rules, and the worse they are the more they breed. So the fewer rules the better. But there is one rule necessary in nomenclature—read the original diagnosis and try to give effect to the author's intention, so as to fit it to modern requirements.

Why is *Sp. cuspidatus* to be the genotype of *Spirifer*? Because it is the first species mentioned. That may be denied, but if it were

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[1] The course of this escarpment is shown in pl. iii of the memoir.

true the first species rule is itself an absurdity. It is just a contrivance to save a compiler's time, relieving him of the necessity of reading an original diagnosis to find out an author's meaning. When the first species has obtained its position, not for a zoological reason, but for an alphabetical, a geological, or a typographical reason, its selection as genotype may result in an absurdity—it may fail to fill the author's diagnosis.

It may be urged that *Sp. cuspidatus* is the monotype of *Spirifer*. That I challenge. I would argue that the description of *S. cuspidatus* is a separate act, not a part of Sowerby's generic diagnosis. That is complete in itself. Supposing that the description of *S. cuspidatus* had been written by another author, then *S. cuspidatus* would not be the genotype of *Spirifer*. Why should it be so because the description was written by Sowerby ?

The diagnosis of *Spirifer* (*Min. Conch.*, ii, Feb., 1816, p. 41) says, "The shells of this genus"; that is plural, that rules out a monotype; the genus is founded on several species which are genosyntypes. This is shown further: "I think this genus will comprehend nearly all the shells retained as *Terebratula* by Lamarck which have a triangular foramen . . . The several individuals in which I have discovered spiral appendages (he mentions Derbyshire, Irish, and Van Diemen's Land specimens) bear a considerable natural affinity to each other, from which circumstance we may venture to place many analogous species in this genus, although their interior has not been fully exposed." That is what he has done with *S. cuspidatus*; he has placed it in *Spirifer* on sufferance; as an analogous species, for he expressly says (p. 43), "I have not discovered the spiral appendages [of *S. cuspidatus*]." That excludes it effectually as the genotype. He placed it in *Spirifer* by intuition; it had the triangular foramen. It was a case of typographical necessity. His material of *Spirifer* with the spirals discovered was held up by the Linnean Society; but the plate of *S. cuspidatus* was ready. It could not be placed in *Terebratula*; it was *Spirifer* by presumption if not by proof. Anyone who has had to draw up lists of species and assign them to new genera will have been confronted with the same difficulty and have committed a similar act.

In choosing a lectotype of *Spirifer* out of these species of Derbyshire, etc., shells, consideration should be given to Sowerby's further writings. First is his description of *S. cuspidatus*, saying, "Spiral appendages . . . may be seen in *Anomia trigonalis* of Martin." That is the first species mentioned. Then in 1818 was published Sowerby's paper in the Linnean Transactions, vol. xii, wherein he figures *Terebratula striata* showing spirals. But in his description of *S. trigonalis* (M.C. ii, pl. cclxiii, p. 117) he admits that he had "confounded it with *Anomia striata* of Martin . . . in the Linnean Transactions". Evidently he had discovered this mistake after the reading of his paper to the Linnean (December, 1814) and before the publication of his description of *S. cuspidatus* (February, 1816), but was unable to alter the name in the Linnean paper, for it would have involved too much explanation. Because, evidently, fig. 1, pl. xxviii, of the Linnean Trans. is a synthetograph—the details of the coils taken from an example of *Anomia trigonalis* (refigured M.C. ii, pl. cxxv, fig. 1) enlarged, revised, and adapted to an outline of *An. striata*; the large specimen of which he evidently used as the basis of his communication. This species he had from Derbyshire and Cork (M.C. ii, p. 125).

The genosyntypes, therefore, of Sowerby's *Spirifer* are really the *Terebratulæ* of Lamarck with triangular foramen, the *Anomitæ* figured and named by Martin, in which Sowerby had found spirals (M.C. ii, pp. 141, 142). These are *An. striata* and *An. trigonalis* which he had confounded with it—the Van Diemen's Land specimens may be ruled out. The authors who have chosen *An. striata* to be the genolectotype seem to be quite within their right. In that case, choice having been made, it stands good.

On the Distribution of *Productus humerosus* (=*sublaevis*) and the Zonal Range of the "Brachiopod Beds" of the Midlands.

By Professor T. Franklin Sibly, D.Sc., F.G.S., Armstrong College, Newcastle-upon-Tyne.

IN 1908 the *Productus humerosus* beds in the Carboniferous Limestone of Caldon Low, N. Staffs, were tentatively assigned to the Lower *Dibunophyllum* zone, D_1, of Vaughan's classification. The slender evidence for this correlation was set out in my paper on the Midland Area.[1]

More recently the researches of Mr. L. M. Parsons in Leicestershire have established the *Dibunophyllum* age of the well-known *Productus humerosus* beds of Breedon-on-the-Hill and Breedon Cloud. Mr. Parsons showed that the dolomites with *Productus humerosus* in those localities contain *Cyrtina septosa*, a well-known D_1 shell; that they are overlain conformably by dolomites with chert which yield, at Breedon Cloud, a rich D_{2-3} fauna of corals and brachiopods; and, further, that they are underlain conformably, at Breedon-on-the-Hill, by beds with *Lithostrotion irregulare* and *Cyathophyllum* aff. *murchisoni*.[2] The position of the *Productus humerosus* beds of Leicestershire at the top of the subzone D_1 was thus firmly indicated, and the above-mentioned correlation of the beds at Caldon Low incidentally received confirmation.

In the interval it had become known, through the researches of Delépine and Vaughan, that *Productus sublævis* de Koninck, a species which includes *Pr. humerosus*, Sowerby, occurs persistently and abundantly on a much lower horizon in Belgium and in the

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[1] Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 44.

[2] Ibid., vol. lxxiii, 1918, pp. 94–100.

Clitheroe district of Lancashire, namely, in the upper part of the *Caninia* zone (C_2).[1]

It is, therefore, evident that *Productus sublævis* occurs abundantly on two widely different levels in the Avonian, one in the Upper *Caninia* Zone, the other at the top of the Lower *Dibunophyllum* Zone. Dr. Wheelton Hind, in questioning Mr. Parsons's reference of the *humerosus* beds of Leicestershire to D_1, and at the same time affirming his own belief in a *Caninia* age for the *humerosus* beds of Caldon Low, failed to take this view.[2]

Strong confirmation of the *Dibunophyllum* age of the Caldon Low beds is now supplied by Mr. J. Wilfrid Jackson's discovery of *Productus humerosus* in limestones of "Brachiopod Bed" type in Dove Dale, only a few miles to the north-east of Caldon Low.[3]

The "Brachiopod Beds" of North Staffordshire and Derbyshire were described by me as an abnormal facies, and assigned to D_2, with the qualifying remark that they possibly encroach upon D_3.[4] They have long been accepted as "knoll-reef" deposits of D_2–D_3 age, paralleled by the upper or Cracoe knolls in the Clitheroe–Craven region of Lancashire, and by the massif of Visé, in Belgium. It is, however, most interesting to find in Mr. Jackson's account of the occurrence of *Productus humerosus* in Dove Dale, evidence which definitely suggests that the "Brachiopod Bed" phase in the Midlands ranges downwards into D_1. The limestones bearing *Pr. humerosus* in Dove Dale are clearly of "knoll-reef" type, both in their faunal characteristics and in their lithic structure; and the top of D_1 is at once suggested as their horizon by a consideration of the *humerosus* beds of Leicestershire. It may be remarked that if the *humerosus* beds of Dove Dale lie some 500 feet below the top of the Carboniferous Limestone, as suggested in Mr. Jackson's account of them, then their stratigraphical position corresponds rather closely with that of the D_1–D_2 boundary as roughly determined in the Buxton-Longstone traverse of the Midland area.[5]

In concluding this note I take the opportunity of expressing the interest with which I am following Mr. J. W. Jackson's researches in the western part of the Midland area, a tract which was most inadequately studied by myself, and the hope that he will succeed

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[1] "In the Franco-Belgian area the early, smooth form of *Pr. sublævis* occurs in a persistent band between Tournaisian and Viséan. In the South-Western Province this mutation is very rare; it has, however, been recorded from the C_2 oolite of Burrington. In the Clitheroe area, the early *Pr. sublævis* enters at the top of C_1 and forms a persistent band at the top of C_2 (as in Belgium)." (A. Vaughan, Quart. Journ. Geol. Soc., vol. lxxi, 1915–17, p. 47.)

[2] Geol. Mag., 1918, p. 480. Dr. Hind quoted the occurrence of *Cyrtina septosa* in the *humerosus* beds of Leicestershire as one indication of *Caninia* age as against D_1 age, notwithstanding the fact that *Cyrtina septosa* occurs in D_1 of Derbyshire and the South-Western Province, and characterizes a persistent band in D_1 of the North-Western Province.

[3] Geol. Mag., Vol. LVI, 1919, p. 335 and pp. 507–9.

[4] Quart. Journ. Geol. Soc., vol. lxiv, 1908, pp. 47–50.

[5] Ibid., vol. lxiv, 1908, p. 39, fig. 2.

in throwing further light upon the problem of the "Brachiopod Beds". Little or nothing is yet known regarding the transition from these "knoll-reef" deposits into the standard limestones of the district, while their rich fauna affords a great field for discriminating study.

The Pygidium of the Trilobite.

By Percy E. Raymond, Ph.D., Harvard University, Cambridge, Massachusetts, U.S.A.

ALTHOUGH the process of development of the pygidium in the trilobite has been known since the time of Barrande, its significance does not appear to have been appreciated, and much of the modern speculation on the classification of trilobites is based upon the erroneous idea that those species whose form is most annelidan are most primitive. As a matter of fact, the study of both morphology and ontogeny shows that in this group the large pygidium is primitive and the small one specialized.

The growing point in trilobites is, as in all other arthropods, immediately in front of the anal segment. This was proved by Beecher from a study of the appendages of *Triarthrus*, and is confirmed by facts more recently afforded by specimens of *Neolenus* and *Cryptolithus* having the appendages attached. New segments must, therefore, be introduced during moults, and each is pushed forward through the pygidium by those which are added later. While these segments are, as thus introduced, potentially free, they do not actually become so until they are pushed off from the anterior end of the pygidium. The thorax, therefore, grows through the degeneration of the pygidium. This process can be seen in the ontogeny of all species where any considerable number of growth-stages are known, but can be studied in greater detail in Barrande's classic descriptions of *Sao hirsuta* and *Dalmanites socialis*. In all cases it is found that the pygidium of the protaspis is proportionally larger than at any later stage in the life-history, and this is equally true of an elongate Mesonacid or of a Phacopid such as *Dalmanites*. If the proportional length of the pygidium of *Sao* at various stages be examined, it will be found that in the very smallest protaspis it is about 30 per cent of the whole, at a length of 1 mm., while there are still no free segments, the animal is practically isopygous, and from this stage to a length of 7 mm. the proportional length steadily drops to the 7 or 8 per cent which remains in the adult. All trilobites, whether the adult has a large or a small pygidium, show this same process, and Troedsson has recently described a particularly interesting case. The pygidium of *Dalmanites eucentrus* (Angelin), when 1·28 mm. long, has eight pairs of pleural ribs, indicating the possession at that stage of two more segments than the adult.[1] This case is of the more importance on account of the

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[1] Lunds Univ. Årsskr., n.f. avd. 2, bd. 15, nr. 3, 1918, pp. 57–67, pl. i, fig. 23.

close relationship of *D. eucentrus* and *D. mucronatus*. The latter species appears first in the *Staurocephalus* beds, which are beneath the Brachiopod Shales containing *D. eucentrus*. The pygidium of the adult *D. mucronatus* is larger than that of the other species, having eight pairs of pleural lobes. In short, *D. eucentrus* seems to be descended from *D. mucronatus*, and in its youth passes through a stage in which it has a large pygidium like the latter.

All of this shows that the free segments of the thorax become such by the breaking down of a large pygidium, and that a small pygidium is the result of the degeneration of a large one. Further, that a large pygidium is not made up by the fusion of segments once free, and so is not a specialized organ in the sense that the metasomic shield of *Limulus* is.

If trilobites be examined with the assistance of these facts, rather than with the aid of the theory of origin from a numerously segmented annelid, much of the supposed specialization of Hypoparian trilobites disappears. The Agnostidæ, Eodiscidæ, Trinucleidæ, and the like are doubtless specialized—nothing which is not specialized can exist—but they are specialized simple trilobites. This is shown not only by the small number of free segments and relatively large pygidia, but by the absence of compound eyes and the presence of marginal or submarginal facial sutures, features in which they agree with the simplest type of protaspis.

THE PYGIDIUM IN THE AGNOSTIDÆ.

As to which shield is which in the Agnostidæ, I can only say that I have exhausted the collections accessible to me in searching for a specimen retaining the hypostoma. I have brought the case to the attention of Doctor Walcott and his assistants, and Mr. B. F. Howell, of Princeton University, is going to make a special search in the shale of the Middle Cambrian of South-Eastern Newfoundland this summer. I appeal to any student having specimens preserved in shale to make an attempt to find a specimen with the hypostoma in position. There are other possible lines of evidence, but none so satisfactory. Pending such evidence it may be pointed out that no other trilobite has a free plate on the ventral side of the pygidium, that Wahlenberg, Dalman, Brown, and Hisinger used an orientation the reverse of that now accepted, and that as now placed the tips of the pleuræ of the thoracic segments curve forward instead of backward as in other trilobites. If one take plate vi of Angelin's *Palæontologia Scandinavica* and reverse it, he will find that all of the figures appear more natural. In the accepted position the tips of the pleuræ of the thoracic segments and the pleural furrows point forward. In the reversed position they point backward, as in all other trilobites. In the accepted position every species has a tubercle on the median line of the pygidium. In the reversed position this would be on the cephalon, where it would more naturally occur. In the accepted position, the "glabella" is less furrowed than the axial lobe of the "pygidium", a condition unusual among trilobites. In the reversed position, the axial lobe of the anterior shield usually shows three pairs of furrows, the normal number of glabellar furrows in most trilobites.

The only valid objection which I can see to reversing the usual orientation is that in the new position the segments would overlap in a direction opposite from that of all other Crustacea. That difficulty appears to be a serious and fundamental one.

THE PROTASPIS.

Professor Swinnerton has introduced a new point of view, but one which might have been expected, by suggesting that the protaspis is a specialized larva, adapted to a planktonic mode of life, and that characteristics derived from its later development have no phyletic significance.[1] This is, of course, the view which has lately been held by nearly all zoologists concerning the nauplius of recent Crustacea, and both views have their origin in the "annelid" theory. Why, if trilobites were evolved directly from benthonic annelids, did they not retain the old planktonic trochophore, instead of evolving a new type, which in no way resembled the supposed ancestor or its larva?

Swinnerton says that the larvæ of the Mesonacidæ are the most primitive known. That may be true, as they are certainly the most ancient, but he continues to overlook the fact that the very youngest stage of the Mesonacid larva has not yet been found. Beecher pointed this out, and roughly figured a specimen younger than any illustrated by Ford or Walcott.[2] The eyes of this specimen were very nearly marginal, and in the youngest protaspis probably were actually on the edge. Beecher had worked over the Ford collection of larval Mesonacidæ, and certainly did not ignore them in making his classification. As a protaspis, the larva of the Mesonacidæ does not differ fundamentally from that of other trilobites, but the development is different, because of the absence of facial sutures.

Irrespective of the presence or absence of eyes, the circular or broadly oval form of the protaspis shows that beyond question it was a member of the plankton. But the evidence seems to indicate that it was not there as a secondarily adapted larva, but because its ancestors occupied that habitat. The broad lateral expansions (pleural lobes) present in larva and adult alike gave to the trilobites a shell which was easily kept afloat, and while not adapted to rapid swimming was a source of buoyancy. It has been shown above that the large pygidium is primary, that is, those trilobites are most primitive which are best adapted to keep afloat, and those most specialized which become adapted, by assuming a worm-like form, to crawling

[1] GEOL. MAG., Vol. LVI, 1919, p. 109.

[2] *Amer. Geol.*, vol. xvi, 1895, p. 175, fig. 6.

life on the bottom. As had already been suggested, first, I believe, by Spencer, the pygidium was probably used as a caudal fin, perhaps more in the manner of the up and down motion of the tail of *Sagitta* than in the spasmodic flaps of a lobster. That the longitudinal muscles had considerable power, however, is shown by the great widening of the axial lobes of many trilobites with large pygidia. The appendages also show that most trilobites were swimmers as well as crawlers, though none so far investigated show any particular adaptation for the purpose of swimming except *Triarthrus*, whose pygidium is small.

The trilobite was not a powerful swimmer, but on the other hand it was not in any case entirely specialized for bottom life. The need for a floating type of larva was not great, since floating characteristics dominate over crawling characteristics in the adults, and thus such evidence as exists points to a pelagic rather than a benthonic ancestor for the group.

BACKWARD MIGRATION OF THE EYES.

Beecher made no attempt to explain this migration, which formed so fundamental a feature in his classification. Two factors seem to be involved. In many cases there was little actual change of position, but the eyes of the adult are relatively further back because the brim in front of them has grown outward. In others there is actual backward translation, and this seems to be due to the increase in size of the anterior digestive portion of the alimentary canal, which bulges out the anterior end of the glabella, pushes back the mouth, and doubtless, the eyes, their nerves and ganglia. This enlargement of the "stomach" is probably correlated with the change from a planktonic mode of life, where the food was chiefly the concentrated micro-organisms, to the benthonic habitat, where an omnivorous or even vegetable diet may have been adopted. This change, though one of food, seems to have been so fundamental that its results became impressed upon the race, and thus the position of the eyes came to be of classificatory importance.

I think it will be evident from what has been said above that trilobites as unlike as *Cryptolithus*, *Harpes*, and *Dionide* could be descended from an *Agnostus*-like ancestor, and that those who wish to place the Agnostidæ and Trinucleidæ among the degenerate animals must bring forward some proof for their assertions which is not based upon the theory that trilobites descended from benthonic annelids. For further details and a full statement of the ideas expressed above, the reader is referred to a memoir by the author that is shortly to be published by the Connecticut Academy of Arts and Sciences.

The Ammonite Siphuncle.

By A. E. Trueman, D.Sc., F.G.S., University College, Cardiff.

It is well known that the chambers of Cephalopod shells are connected by an organ called the siphuncle, which passes through the septa by the septal necks. Many investigators who have studied these shells have made careful observations on the siphuncle, hoping thereby to throw light on its functions. Such workers as Branco, Blake, Zittel, and Owen, among many others, have written on this problem, while more recently an elaborate study of the structure and constitution of the siphuncle has been made by Grandjean,[1] who gives a detailed account of the organs associated with it. Among the many points established by Grandjean's work, not the least interesting is the fact that the siphuncular tube of Ammonites and Belemnites is composed of calcium phosphate, and not, as had previously been stated, of calcium carbonate.[2] But in spite of Grandjean's careful examination of the less obvious characters of the siphuncle, it appears that certain facts, much more easily observed, have hitherto been overlooked.

Terms.

The word " siphuncle " in Ammonite literature is used somewhat loosely, just as the word " siphon " is used in the same connexion by French authors. As Grandjean pointed out, however, the " siphon " (or siphuncle) proper is a membranous organ; the tube of calcium phosphate found in fossils, and commonly referred to as the siphuncle, is simply the solid sheath, which it will be more convenient for the present purpose to call the siphuncular tube or envelope.

Continuity of the Siphuncular Tube.

When examining some large sections of Ammonites the writer noticed that the siphuncular tube was not continuous through all the chambers to the body-chamber, even when the sections were perfectly median. It was at first thought that this was an unusual character, but when other sections were examined similar facts were noticed, and a more systematic inquiry was therefore undertaken. Ammonites were examined by kind permission in the College and Museum collections at Bristol, Cardiff, and Nottingham, and while only a small proportion of the ammonites seen were sufficiently complete or accurately cut to give the desired information, in every specimen which showed enough detail the same rule was found to hold good.

A section of *Asteroceras obtusum* (Sow.), of diameter 70 mm. in the

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[1] F. Grandjean " Le Siphon des Ammonites et des Belemnites ": Bull. Soc. Géol., France, ser. iv, vol. x, 1910, p. 496.

[2] This further point of resemblance between Ammonites and Belemnites is interesting in view of Dr. W. D. Lang's recent suggestion concerning their classification (Proc. Geol. Assoc., vol. xxx, p. 59).

Natural History Museum, Nottingham, shown diagrammatically in Fig. 1, will serve to illustrate the character in question. That the section is cut accurately along the median plane is shown by the position of the keel and the size of the septal necks for the passage of the siphuncle. The siphuncular tube can be clearly seen along the greater part of the spiral, but after a diameter of 38 mm. (S, Fig. 1) no trace of the siphuncular tube can be made out in the succeeding ten chambers. The wide septal necks in the section at that point show that its non-appearance is not due to asymmetry.[1] Apparently the only conclusion that can be drawn, therefore, is that the siphuncle, which was, of course, continuous throughout the spiral, had an envelope which did not extend through the ten chambers preceding the living chamber.

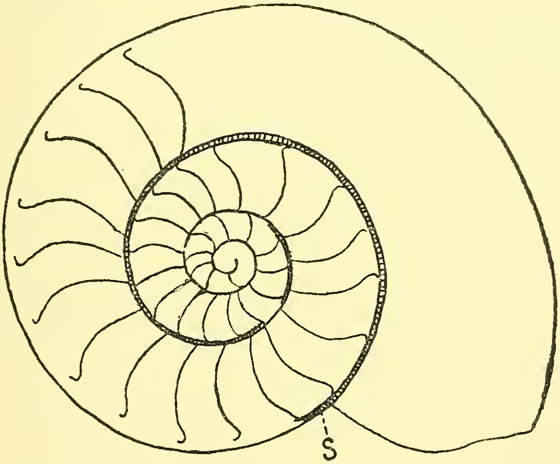

Fig. 1.—Diagram of a section of *Asteroceras obtusum* (Sow.) showing the siphuncular envelope (S).

Similar facts were also observed in the following Ammonites :—

1. A large unidentified specimen from the Inferior Oolite in University College, Cardiff. Diameter 330 mm. Part of living chamber present. Six chambers without a siphuncular envelope. These six chambers and the living chamber are filled with oolite, the earlier chambers with calcite.

2. *Parkinsonia* sp. University College, Nottingham. A specimen, diameter 240 mm., septate throughout (that is, with no part of the body-chamber retained), has no siphuncular tube in the last three-quarters of a whorl. That is, for at least fifteen chambers there was no siphuncular envelope.

3. *Deroceras* sp. Natural History Museum, Nottingham. Diameter 85 mm. Septate throughout. No siphuncular tube after diameter 44 mm., that is, at least fifteen chambers without.

4. *Harpoceras exaratum.* University College, Cardiff. Diameter 76 mm.

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[1] Further, asymmetry is of extremely rare occurrence in such keeled ammonites. See Swinnerton & Trueman, Quart. Journ. Geol. Soc., vol. lxxiii, 1918, p. 54.

Portion of living chamber present. No siphuncular envelope after 43 mm., that is, twelve chambers without.

5. *Oxynoticeras oxynotum.* Welsh National Museum. Has no siphuncular tube for twenty-five chambers, the whole of the last whorl.

6. ? *Lioceras* sp. Bristol University. Diameter about 150 mm. Body-chamber present. No siphuncular tube in last nine chambers. The body-chamber and the preceding nine chambers have oolite filling, the earlier chambers have calcite.

It frequently happens that while the chambers of an Ammonite are filled with calcite or other crystals, the body-chamber is filled with material such as clay or oolite, which was able to get in when the animal decayed. But in several of the Ammonites referred to above, not only the body-chamber, but also the chambers without a siphuncular tube, were filled with such material, probably indicating that when the Ammonite died the siphuncle decayed, allowing detrital material to enter those chambers where there was no siphuncular tube. Using this type of evidence it would be possible to extend the above list very considerably.

OTHER INDICATIONS OF A DISCONTINUOUS SIPHUNCULAR TUBE.

While the most obvious way of investigating the continuity of the siphuncular tube is by means of median sections, yet useful information concerning some Ammonites has been obtained from casts and impressions. These cases may be considered in three groups :—

1. In some casts of Ammonites, especially those which have been rubbed or polished, the siphuncular tube may be seen along the external margin. In such casts it was found that the siphuncular tube did not continue unbroken to the body-chamber.

For instance, a polished cast of an unidentifiable Ammonite in the teaching collection at University College, Cardiff, has a continuous siphuncular tube up to a diameter of 175 mm. Following this are three chambers, the remainder of the shell not being present. The siphuncular envelope in these chambers is discontinuous (see Fig. 2). In the last two chambers short portions of the tube (S 2, S 3) are attached to the front septal neck only ; in the third chamber the portion of the tube is free (S 1) and on the side of the cast. It appears, therefore, that the tube was discontinuous in these chambers (and in any others in front that may originally have been present), and that the secretion of the solid tube commenced between the septa, each portion becoming attached to the septal neck in front. With the death of the animal the siphuncle decayed, and these portions of the tube were unsupported, and the shell having fallen on its side they either hung loosely from their attached ends (S 2, S 3) or slipped along the inside of the shell (S 1).

A similar condition is shown by an example of *Hoplites deshayesi* (Leym.) in the Welsh National Museum. In this specimen part of the living chamber is present at a diameter of 70 mm. The siphuncular tube appears on the outside of the cast as a continuous black band, passing through all but the last two chambers. In the last chamber no trace of any siphuncular tube can be seen, but in the preceding one a short portion of the tube has slipped along the side exactly as in Fig. 2 (S 1).

These two cases suggest that in some of the sections described the apparent absence of any siphuncular tube may be similarly due to the falling away of the inter-septal portions of the tube. Nevertheless, there is no doubt that the tube was not present in the last few chambers of all the specimens mentioned.

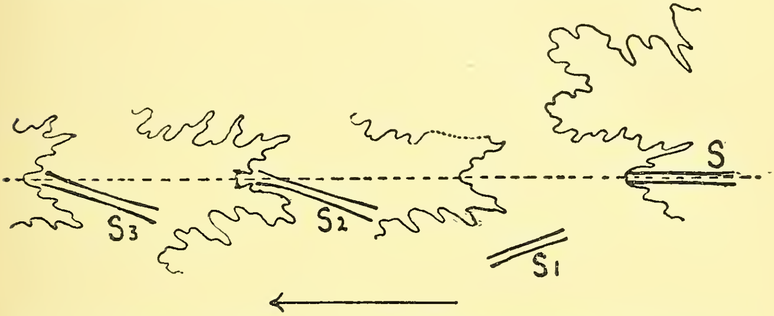

Fig. 2:—Diagram showing the discontinuous siphuncular tube in a Hildoceratid Ammonite. S represents part of the normal siphuncular tube, with loose portions at S_1, S_2, and S_3.

2. Casts of *Aetomoceras scipionianum* (d'Orb.) and allied forms found in the phosphatic beds at Radstock, Somerset, afford further confirmation. The siphuncular tube is generally broken away, leaving a groove along the external margin, but the keel is still present on the cast of the body-chamber and on several chambers preceding it. This suggests that there was no siphuncular tube in those chambers, otherwise it would also have been broken away.

3. Many specimens of *Psiloceras* cf. *planorbe* (Sow.), found in the Lias at Lavernock, near Cardiff, have been flattened in preservation, and in many cases the shell was evidently so thin that it is only now represented by the outer horny layer. This is soon worn or even blown away, and then the impression often shows the siphuncular tube as a white band running round the spiral.[1] As this does not extend into the outer two whorls it is extremely probable that here again there was no siphuncular tube in the last few chambers.

THE SIPHUNCULAR TUBE IN YOUNG AMMONITES.

There are two possible explanations of this absence or incompleteness of the siphuncular envelope in the last few chambers

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[1] Mr. F. F. Miskin, F.G.S., kindly examined a number of these Ammonites, and proved that this white material was calcium phosphate, and therefore represents the siphuncular tube.

of Ammonites. It may have been an old-age or adult character, indicating feebleness of powers of phosphate secretion, or it may have been a normal feature of growth, the envelope being formed by a siphuncle but always leaving several chambers in which it was incomplete.

To test the truth of this latter suggestion sections were cut through a number of young Ammonites, those selected being young individuals with at least a portion of the body-chamber preserved, and not simply the inner whorls of adults. In each example investigated it was found that in the chambers preceding the living chamber there was no siphuncular envelope.

The following specimens were cut :—

Hildoceras cf. *bifrons* (Brug.), from Grantham. Diameter 24 mm. Scarcely any sign of a siphuncular envelope in the last whorl.

Dactylioceras sp. from Grantham. Diameter 3·5 mm. No siphuncular tube in last two chambers.

Amblycoceras sp. from Leckhampton. Diameter 4·2 mm. No siphuncular tube in last three chambers.

It therefore appears that in many, if not all, ammonites, young and old, the siphuncle is without an envelope in the chambers preceding the body-chamber. The number of chambers in which there is no envelope apparently increases with the age of the individual, but probably depends on other conditions also.

PREVIOUS OBSERVATIONS ON THE EXTENT OF THE SIPHUNCULAR TUBE.

So far as the writer is aware, this incompleteness of the siphuncular envelope has not previously been recorded, although, curiously enough, Zittel has described an exactly opposite instance.[1] In some casts of *A. elimatus* from Williamswitz the siphuncular tube is not preserved, and the groove which presumably marks its position appears to persist a short way into the body-chamber. Beyond this Zittel gives no information, and apparently did not refer to it further in his later works. While this observation may indicate that in some species or individuals the secretion of an envelope proceeded more quickly than in those described above, it is doubtful whether the secretion actually occurred within the body-chambers, and it must be pointed out that Zittel was relying for his evidence not on the actual siphuncular envelope but on the extent of a groove which may have contained it.

Grandjean suggested that Zittel's observation affords a possible explanation of the formation of the siphonal membranes, the association of which with the covered siphuncle he was unable to understand.[2] It may be briefly noted that the facts recorded above make it possible to give an equally simple explanation.

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[1] In Oppel, Palæont. Mitt. Mus. d. k. bayer. Staates, Bd. ii, 1868, pp. 79–80. I have to thank Mr. F. T. Ingham, B.Sc., for supplying particulars of this paper.

[2] Op. cit., p. 502.

FUNCTION OF THE SIPHUNCLE.

It is not the writer's intention to enter into any lengthy speculation concerning the use of the siphuncle either among Ammonites or nautiloids. Many writers have dealt with the question, and nearly every one has a different explanation to offer. A summary of a number of these suggestions is given by Blake,[1] and many others have been briefly discussed by Zittel.[2] It will, however, be interesting to re-examine several of these theories in the light of the observations recorded.

The early conception of the Ammonite shell was as an apparatus by which the animal could float on the surface of the sea, or by diminishing the amount of gas in the chambers could sink to the bottom. Various writers suggested ways in which this might have been accomplished, some imagining a siphuncle which was capable of expanding and so expelling the gas, others suggesting that the siphuncle introduced fluid into the chambers and so achieved the same result.[3] Both these suggestions were deemed by most writers to be inadmissible when it was found that the siphuncle was surrounded by a solid envelope. But if, as we have noticed, in the last few chambers the siphuncle had no envelope, this objection no longer holds, for a very small change in density would suffice to lower or to raise the shell, and this could be made by altering the contents of the last few chambers only.[4] Nevertheless, the author would not for a moment suggest that the siphuncle performed any such function.

In a recent paper Mr. L. F. Spath has put forward another suggestion concerning the use of the siphuncle in *Nautilus*.[5] He considers that this strong central siphuncle of *Nautilus* helps to prevent the animal from falling away from its shell when it moves forward to form a fresh septum. Apparently this suggestion is based on the somewhat amusing but scarcely scientific account of the capture of a specimen of *Nautilus pompilius* written by a lady and quoted by E. A. Smith.[6] According to this story the animal breaking its siphuncle fell from its shell and *showed no desire to re-enter it*! Against this may be given the experience of Dr. Willey, who made saw-cuts in the shells of *Nautilus* and cut the siphuncles just behind the body, yet the animals lived on, and apparently showed no tendency to fall from their shells.[7] It is fairly certain, therefore,

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[1] J. F. Blake, *British Fossil Cephalopods*, vol. i, 1882, p. 39.

[2] K. v. Zittel, *Handbuch der Palaeont.*, Bd. ii, pt. i, p. 348.

[3] T. Wright, *Monograph of Lias Ammonites*, Palæont. Soc., 1878-86, p. 174.

[4] The total weight of the ammonite animal and its gas-filled shell was probably not very different from the weight of water it displaced. See Dr. F. Willey, *The Pearly Nautilus*, 1902, p. 747.

[5] L. F. Spath, "Notes on Ammonites": GEOL. MAG., Vol. LVI, 1919, p. 30.

[6] E. A. Smith, "Note on the Pearly Nautilus": Journ. Conch., October, 1887.

[7] Op. cit., p. 760.

that the siphuncle in *Nautilus* can hardly serve for such a purpose as Mr. Spath suggests. The animal would fit sufficiently tightly in the shell to prevent its falling out, even when the shell muscles were detached.[1] For instance, some force is needed to pull a dead gastropod, such as a snail, from its shell even after the muscle attachment is broken.

Without discussing at any greater length the functions of the Ammonite siphuncle it may be mentioned that in the writer's opinion the suggestions of Foord[2] and Dr. Henry Woodward[3] are much more reasonable than those mentioned above. These writers suggest that the siphuncle was of more importance in the young animal, perhaps then serving for attachment, but that later on this function was performed by the shell muscles. It is not unlikely also that the siphuncle was of much greater importance in the early stages of Cephalopod evolution than it is in Mesozoic and recent forms. This will be more clearly recognized when an attempt is made to assign a function to the siphuncle of a Belemnite, where it is almost certainly nothing more than the remains of an organ which was probably of value in the early history of the race, and perhaps in the early development of the individual. The tendency for the secretion of the siphuncular envelope in Ammonites to lag behind shell-growth suggests that the value of the siphuncle may at least have been declining.

Angra Pequena (Lüderitzbucht) and Subaerial Denudation.

By R. F. Rand, M.D.

IN recent years the name of Angra Pequena, conferred by Bartholomew Diaz, has been somewhat obscured by the designation Lüderitzbucht, the name given to this port during the German occupation. The latter name still holds, although a compromise, whereby the geographical area should retain the old name and the town be known as Lüderitz, seems desirable.

Angra Pequena (Lüderitzbucht) and Walfisch Bay are the only two useful harbours of the South-West African Protectorate. Apart from its harbour, the town of Lüderitzbucht and the surrounding district have received much attention owing to the considerable finds of diamonds which have been made along the coast, both to the north and to the south of the port.

To the geologist the Angra Pequena area is of interest as affording

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[1] This would be equally true of Ammonites, in which Mr. Spath suggests that the complex lobes and saddles served as an attachment. See also Dr. W. D. Lang, "The Evolution of Ammonites": Proc. Geol. Assoc., vol. xxx, 1919, p. 63.

[2] H. O. Foord, *Catalogue of Fossil Cephalopods in Brit. Mus.*, vol. i, 1888, pp. 10–11.

[3] H. Woodward, *Pop. Sci. Review*, vol. xi, 1872, p. 113.

an admirable instance of æolian denudation. It is a desert area, a region of rock and sand. The average annual rainfall is 0·78 in. There are no running streams. Water for drinking purposes must be imported or distilled from sea-water.

The rocks are of the ancient metamorphic complex, so widespread over the Protectorate. A confused medley of granite, aplite, gneiss, and schists. There is much commingling of types as a result of injection, pressure, and earth-movement.

Overlooking the town of Lüderitzbucht there is a rocky eminence, known locally as the Diamantberg, which within an area of a square mile or so shows many types. The prevailing one is, perhaps, a biotite-schist, which in many places has been invaded to a varying degree by granite or by aplite. The difference in colour between the schistose and the granitic elements shows up the degree of admixture very clearly. In some places masses of schist are to be seen uninvaded by granite, in others masses of granite or of aplite occur without trace of schist. Here and there are large segregations of quartz. Veins and eyes of felspar are common. The rocks are exposed upon every side, for there is no vegetation that counts to mask or protect them.

Although the rainfall is so small the country is carved into hill and valley, and ravines course down the steeper slopes. The floors of the valleys are occupied by mixed sand and grit, a fluent medium, which is disposed much as water would be in a non-desert area, broadening as the valley opens out, narrowing as it closes in like a sand river-bed, which frequently provides the most convenient highway for man and beast. Heat by day and cold by night have their due effect no doubt, but it is the wind which is mainly responsible for the large quantities of rock-waste and debris which litter the surface upon all sides, and for the honeycombing the rocks have so frequently undergone.

The great destructive wind of this area blows from the S.S.W. It is a seasonal wind blowing from October until April. Years ago Andersson noted its effects upon the habits of certain birds. Perhaps only a light breeze in the morning, it rises to a gale in the afternoon, dying down again after nightfall. From time to time there are calm days. It is a wind laden with salt and with moisture where it first strikes the land; thereafter it lays the desert under tribute, and armed with grit and sand scours everything in its path.

No rock entirely withstands the attack. Effects vary. It is rather curious to see how in large boulders, say, of granite, apparently of even texture throughout, one portion of the mass may be merely dull polished and lightly scooped out, whilst another portion is deeply bitten into.

The biotite-schist shows the ravages conspicuously. The rock is pitted, riddled, and holed, with "worm-eaten", honeycombed effect. It rots away. Near to the sea, no doubt, the salt in the air, owing to its chemical reaction with the ferruginous element of the schist, adds to the destructive effect.

The holes bored into the rock are usually more or less circular in outline at the inlet, and burrow into the rock to varying depths. The cavities worn are chambered out and frequently coalesce, giving rise to cells and caves which are sometimes large enough to shelter man.

Should granite and schist have been rolled out into even, alternate laminæ, and the constituent minerals disposed in order, the holes may be regular in size and lie in a straight line. If equidistant, as they sometimes are, they may look as though drilled by human hand. Sometimes the outlines are quadrangular, and the rows may even suggest the pigeonholes in an office desk. There may be simply smoothing and dull-polishing of such a rock, and should the layers crop out vertically they show ridge and furrow, the harder granite being in relief.

Where there has been intimate admixture of felspar and schist the more resistant felspar stands out in studs. The veins of felspar also project, but with their sides unsupported the felspar is at the mercy of its main cleavages and falls in fragments. High up upon cliff-faces one may see holes which resemble those made by martins in some hospitable sandbank.

The granite varies very much in its resistance. Sometimes it is deeply holed and cavernous; sometimes it shells away in concentric flakes; sometimes it shows good resistance and is merely dull-polished.

The segregations of quartz are, as one would suppose, very resistant. Such masses have their surfaces more or less polished and lightly scooped out into shallow depressions of varying size. All salient angles are rounded off. There is a general smoothing over. Pitting, in quartz, when it occurs, is usually small and due to the breaking down of small less-resistant inclusions. Yet the foot of a quartz slope is littered with angular fragments, owing, apparently, to the minute fissures and joints which traverse the mass.

Most of the holes one sees, whatever the nature or texture of the rock, are driven more or less horizontally inwards, after the fashion of adits, but holes are sunk downwards also. The chemical action of the wind-borne salt and moisture, and the grind of the air-driven sand and grit, sap at all vulnerable surfaces. As the holes deepen they come more and more under the swirling effect and scour of the rock-fragments, sand, and grit which they come to harbour. They may be regarded as æolian "pot-holes".

The lofty sides of the ravines and gullies have their rocks deeply honeycombed and wind-bitten. Air-currents frequently course up or down them with violence. The holes may face up or down the ravine. Perhaps there are more which face downwards. Air-currents in broken country are so capricious and so easily deflected that there can be little rule.

One has to see the large quantities of waste littering the surface to realize the rapid rate at which the rock is being destroyed, and one has to experience the force of the wind adequately to estimate its driving power from its set quarter.

No one doubts that the strong S.S.W. wind has been the agent by which a natural concentration of the diamonds in the valleys of the Lüderitzbucht district has been brought about, a concentration which has made their exploitation economically possible. As the diamonds have not been shown to extend very far inland it has been thought by some that marine agency has had something to do with their occurrence. It has been pointed out that the coast is undergoing slow upheaval, and that diamonds have been found in the material of the "raised beaches" which terrace the hills in certain of the valleys of the littoral. But as to this there seems to be no reason why the enrichment should not have taken place from a landward area, and not necessarily from seawards.

It is quite likely that the S.S.W. wind may be entirely responsible for the denudation of the parent diamond-bearing rock as well as for the concentration of the diamonds after being set free. The occurrence of the diamonds near to the sea is probably due to the fact of the denuding agent being a coastal wind. This coastal wind occupies a stratum which does not reach to any considerable height into the atmosphere. As one proceeds inland the country rises fairly rapidly. In the experience of the writer it may be blowing a gale at Lüderitzbucht, while at Haalenberg, 33 miles inland by rail, and considerably less as the crow flies, the air may be nearly still. Haalenberg is 1,816 feet above sea-level. An arborescent aloe, *Aloe dichotoma,* common in the interior, comes down to about this neighbourhood. It does not reach the coast, it could not withstand the wind, although there are switch forms of vegetation which can bow before the wind, and lowly plants, mostly of fleshy habit, which can win their way as far down as the sea. It would seem that we have in noting the habitat of such arborescent forms as *Aloe dichotoma* a guide to the limitations of the coastal wind in both vertical and lateral planes, and consequently to the area the denudation of which has furnished the diamonds.

The hills lying inland between Lüderitzbucht and Kolmanskop are of metamorphic rock, and in general resemble the Diamantberg. They are not high, and one hill is very much like another. Very curiously the broad effect of the landscape in this region is suggestive of a terrain which has been swept by an ice-sheet. There are the generally rounded outlines, the hummocky effects. The resemblance must be illusory, for subaerial denudation is going on so rapidly that one judges the outlines to have been comparatively recently imposed. The directional trend of the sand-blast may be responsible for the likeness.

REVIEWS.

Summary of Progress of the Geological Survey of Great Britain for 1918. pp. 70, with 3 text-figures. 1919. Price 2*s.* 6*d.* net.

THIS publication forms remarkably interesting reading, for several reasons. In the first place we have at any rate a partial lifting of the veil of secrecy that has shrouded some of the more important work of the Survey during the War, and it is possible to make a shrewd guess at the nature of some of the more recondite investigations undertaken by its officers for the Navy, the Army, and the Air Forces. Besides references to the more obvious but exceedingly necessary advisory work on water supply and road-metal at home and abroad and the geology of mining and tunnelling on the Western Front, we are treated to the briefest cataloguing of such tantalizing items as "Reports on Selection of Quartz-crystals for Anti-Submarine Division of the Admiralty", "Report on use of Hexahedric Crystals of Iron-pyrites by the Germans", "Report on a Prize Cargo", and others of a similarly mysterious nature.

As is natural the activities of the small staff that remained were almost entirely diverted to work of an economic nature, or closely connected with the military and commercial necessities of the country. Under this category come reports on the oil-shales of Scotland, possible potash-bearing rocks from North Wales, copper, arsenic, salt, and cannel coal, with a rather full description of the occurrences of the latter in Scotland. There is also an interesting account of the lead and zinc mines in Scotland, including those of Leadhills and Wanlockhead, Newton Stewart, Tyndrum, and Strontian. A deposit of bauxitic fireclay in Ayrshire has been found to posseess high value as a refractory.

In the way of pure geology the mapping of parts of Banffshire and Aberdeenshire has been revised and a good summary of this work is given. Part of this, by Mr. H. H. Read, has already appeared in the Geological Magazine under the attractive title of "The Two Magmas of Strathbogie".

Seven valuable appendices are added to the report, all dealing with boreholes in different parts of the country, namely, Kent, Lincolnshire, Gloucestershire, Yorkshire, Holywell (Flint), and a place called Gosmore, which from a previous publication appears to be near Hitchin, although this is not here stated.

It is highly satisfactory to find that the issue of the extraordinarily valuable series of special reports on the mineral resources of Great Britain is still actively proceeding, three further volumes on iron-ores having just been issued, and that it is intended to keep the series up to date by the frequent issue of new editions. These publications have evidently filled a gap in the literature of economic geology in this country. The forthcoming volumes will be awaited with much interest, and we may be allowed to hope that a volume or volumes on lead and zinc are now on the way.

R. H. R.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN, VOL. VIII. IRON ORES; HÆMATITES OF WEST CUMBERLAND, LANCASHIRE, AND THE LAKE DISTRICT. By BERNARD SMITH, M.A. Mem. Geol. Surv. pp. 182, with four plates and 29 text-figures. 1919. Price 9*s.* net.

ALL geologists who are in any way interested in economic questions in general and in iron-ores in particular will rejoice at having at length an authoritative and complete account of the hæmatite deposits of north-western England. This is a subject of very great geological and technical importance, as to which reliable information has been singularly lacking, especially as regards later developments. Mr. J. D. Kendall's work on the subject was published over twenty years ago, and since then very little seems to have appeared in connexion with the geological aspects of this great industry.

The Geological Survey is to be congratulated on having found in Mr. Bernard Smith an author who is capable of dealing effectively with all sides of a large and complicated subject. He gives an interesting sketch of the early history of the iron-mines, beginning with the impetus given to commercial enterprise by the foundation of the great abbeys in the twelfth century and gradually leading up to the industrial revolution of 100 years ago, when blast furnaces using coal and coke replaced the primitive bloomeries of the Middle Ages, and eventually led to the establishment of such gigantic enterprises as the Barrow Hæmatite Steel Company, Limited, and the Hodbarrow Mine, with its output of 400,000 tons of ore per annum.

It is, of course, well known that the great importance of this hæmatite ore lies in its remarkably small proportion of phosphorus, which causes it to be eminently adapted to the manufacture of steel by the acid Bessemer process, and so long as the supply lasts the demand for this high-grade ore will inevitably continue. Fortunately there is every reason to believe that great reserves still remain untouched under the Duddon Sands and elsewhere. By the very nature of the case, such irregularly shaped and sporadic masses as these must be difficult to locate, the only means available being actual boring or sinking; purely geological reasoning is not of much avail, though a detailed study of the stratigraphy such as is here given is of much practical value in pointing out likely localities for such experiments.

Geologists will read with much interest Mr. Bernard Smith's lucid exposition of the facts and arguments which have led him to the conclusion that the solutions giving rise to the metasomatic replacement of the Carboniferous Limestone travelled in the main downwards from the overlying New Red rocks; the first stage appears to have been the replacement of the tests of calcareous micro-organisms by compounds of iron, this change afterwards spreading to the fine-grained matrix and being accompanied or followed by a certain amount of silicification. The close connexion existing between ore-bodies and fault-fissures appears to be conclusive evidence of the truth of this explanation. Even the lode-like masses of hæmatite in the Skiddaw Slates and other ancient rocks seem to have been formed by descending solutions. The "sops" of Furness, which are obviously ancient pot-holes, were first filled by calcareous breccia and afterwards metasomatized by iron solutions, and there is no real support for the view that any ore-bodies were deposited in cavernous open spaces in the limestone.

The possible further underground extensions of the ore-field and the amount of probable reserves are fully discussed, and 120 pages are occupied by detailed descriptions of the mines, illustrated by excellent diagrams of the forms of the ore-bodies and their relations to varying rock-structures. It is estimated that the ore proved to exist amounts to about forty-five million tons, while probable reserves unproved, may be ninety million tons, most of this being in Cumberland. The Lancashire field seems to be rapidly approaching exhaustion, only five million tons of ore being actually known to exist.

This memoir is an admirable example of the judicious combination of scientific deduction and practical knowledge that is so highly desirable in the literature of economic geology. R. H. R.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN. Vol. IX, IRON ORES (cont.): SUNDRY UNBEDDED ORES OF DURHAM, EAST CUMBERLAND, NORTH WALES, DERBYSHIRE, THE ISLE OF MAN, BRISTOL DISTRICT, AND SOMERSET, DEVON, AND CORNWALL. By T. C. CANTRILL, R. L. SHERLOCK, and H. DEWEY. Mem. Geol. Surv. pp. 87, with 7 figs. 1919. Price 3*s*. 6*d*. net.

IN this volume we have a useful collected account of some relatively unimportant sources of unbedded ores, partly in the form of replacement deposits and partly as true mineral veins. Some of the occurrences, as those of the Carboniferous Limestone of North Wales, Derbyshire, North Somerset, and Devon, are similar in form and origin to the great hæmatite deposits of North-Western England. In the Isle of Man and in the Coal-measures of Bristol hæmatite occurs in veins, perhaps due to alteration of calcite and dolomite by ferruginous waters from the Trias. The spathic vein-ore of West Somerset, Devon, and Cornwall consists in depth of chalybite, converted near the surface to limonite. In some places spathic ore is associated with fluorspar and galena, and is probably due to heated vapours and solutions derived from igneous magmas.

It is shown that the total reserves in the localities described are insignificant, amounting to perhaps 750,000 tons, as compared with a possible 135 million tons in Cumberland and Lancashire; nevertheless, some of these ores are of good quality, and may eventually become valuable for special purposes. It may be mentioned that the hæmatites of the Forest of Dean and South Wales, which are on a much larger scale, are described in a separate volume.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN. Vol. X, IRON ORES (cont.): THE HÆMATITES OF THE FOREST OF DEAN AND SOUTH WALES. By T. FRANKLIN SIBLY, D.Sc. Mem. Geol. Surv. pp. 92, with 14 figs. 1919. Price 4*s*. net.

IF direct evidence were required of the value to industry of the Geological Survey, none could be more convincing than the series of Special Reports on the Mineral Resources of Great Britain which have been produced during the War. They will appeal to a different and perhaps more practical public than do the Geological Memoirs; but on the other hand it is clear that the high standard of these practical reports could not have been attained without the purely geological researches previously made by the Survey. The present monograph is a welcome addition to the literature of iron-ores. Dr. Sibly describes the features of the hæmatite deposits in the Carboniferous Limestone briefly and lucidly. The explanation of the origin of the hæmatite bodies should be of interest to students of economic geology, as the theory of the metasomatic replacement of the limestone by iron-ore from ferruginous solutions derived from the Trias is satisfying and provides a good example for instructional purposes. If there is any genetic connexion between the ore bodies and the other metasomatic replacement of the limestone by dolomite it is obscure and left unsettled, though there is evidence that dolomite was formed at three periods, so that it is necessary to distinguish between primary dolomite and contemporaneous and subsequent dolomitization. The greater portion of the report deals with accounts of the mines, both working and abandoned. Statistics of output in the past and also estimates of the amount of iron-ore remaining (so-called "reserves") are given, though the author sees no hope for the resuscitation of the mines under present conditions.

Recent Geophysical Reprints.

1. AN APPARATUS FOR GROWING CRYSTALS UNDER CONTROLLED CONDITIONS. J. C. HOSTETTER. Journ. Wash. Acad. Sci., vol. ix, 1919, p. 85.

2. THE HYDRATED FERRIC OXIDES. E. POSNJAK and H. E. MERWIN. Am. Journ. Sci., vol. xlvii, 1919, p. 311.

AS is well known the Geophysical Laboratory of the Carnegie Institute put aside its usual scientific pursuits to help win the War, and on this account only two of the latest issue of reprints from the Laboratory are sufficiently geological to call for notice in these pages.

1. The apparatus for growing crystals described by Hostetter has its origin in a German patent of Krügen & Finke. Its principle is the circulation of solution from a saturator to a crystallizer and back again. The temperature difference varied with the salt used and was generally kept well under 0·5° C. The description is clear, and is illustrated by an admirable diagram.

2. The hydrated ferric oxides, though a difficult subject, have attracted considerable attention in the past. Many of the individual results attained by Posnjak & Merwin are of the nature of confirmation rather than of original discovery, but this does not detract from their importance. Our knowledge in its *toute ensemble* was hopelessly confused, and the present contribution is most welcome. Its main features may be summarized as follows:—

Ferric hydrates, both natural and artificial, fall into two great classes: Class I, orange to orange-yellow; and class II, red to reddish-brown. Class I has the empirical formula $Fe_2O_3.H_2O$, with variable adsorbed and capillary water. Class II is of a different constitution.

Only the natural products have been met with as definite crystals. These are of three kinds: Class I, Goethite and Lepidocrocite; Class II, Turgite.

Limonite falls to Class I. Much of what is commonly called limonite is shown to be fibrous goethite, but other samples are indecipherably "amorphous", and for these the name limonite is retained. Limonite in this restricted sense may or may not be goethite. Its density and refractive index, when corrected for the effect of adsorbed and capillary water, point in the direction of the goethite correlation, but as yet the evidence is not considered conclusive. Might not the absorption spectrum of the streak help to fill in this gap in our knowledge?

Turgite is interpreted as a solid solution of hæmatite and goethite, but in this direction the authors have not developed their case very clearly. They base upon the density of the three minerals, and then remark "all other evidence at hand is in favour of this assumption". But in relation to the dehydration behaviour of turgite, we had previously been told "the shape of the curve plainly signifies that the water in turgite is held in a different way from that in the other hydrated oxides ", and later, " no sudden decomposition takes place anywhere, and it would seem that turgite unlike the other hydrated ferric oxides, is not a definitely hydrated compound." How are these statements to be reconciled with the view that some turgites contain about 50 per cent of goethite ?

Of many other points of interest the following may be chosen :—

(*a*) The orange to orange-yellow hydrates (Class I) are found to begin to decompose at an appreciable rate at about 200° C., while at about 300° C. their decomposition becomes labile.

(*b*) For the same class, dehydration is irreversible where combined water is concerned, and approximately reversible where uncombined water is concerned.

(*c*) For turgite (Class II) dehydration is irreversible, but no temperatures comparable with those referred to in (*a*) have been detected.

In conclusion one may perhaps venture on a complaint. Much might have been gained by clearer exposition. It will suffice to mention a couple of instances of unnecessary obscurity in regard to figure 2 with its fourteen independent graphs. Each graph is numbered, and the reader is referred to two tables elsewhere in the paper to find, by help of these numbers, under what names the fourteen specimens experimented with were received from various museums. It is a matter of further research to realize how far this naming has been accepted by the authors. It would have been a great help to have had the author's naming indicated by initials in the corner of each graph, as, for instance, Li. for limonite. Then again, figure 2 is described as giving " temperature—time dehydration curves ". It appears that each graph in the figure co-ordinates successive temperatures of a hydrate charge with the differences of these temperatures and those of a control body, where both charge and control have been heated in a furnace regulated to raise the control's temperature at a roughly uniform rate. But to make certain of all this one has to turn to previous literature.

E. B. BAILEY.

THE CHANNEL ISLANDS. By JOHN PARKINSON. *Handbuch der regionalen Geologie*, vol. iii, pt. i, pp. 335–41. Heidelberg, 1916.

IN Steinmann's *Handbuch der regionalen Geologie*, Mr. John Parkinson gives a clear outline of the Geology of the Channel Islands, a subject to which he made formerly some valuable contributions. It is illustrated by geological sections and small maps of the principal islands. In Jersey the oldest sedimentary rocks are probably Brioverian, and in them are some contemporary volcanic rocks, ending with the remarkable rhyolites of Boulay Bay and Anne Port. Intrusive granites and diorites also occur, the latter being the older. There are some raised beaches, and a cave has yielded palæoliths of Mousterian age, and nine human teeth of primitive Neanderthal type. Alderney consists of diorite, varying from a very basic form to a tonalite, with a grit (*grès felspathique*) of early Arenig age. Diorite, tonalite, hornblende schist, and banded granulites make up Sark. In Guernsey the southern and larger portion is a somewhat variable gneiss, a pressure-modified more or less porphyritic granite, the oldest rock in the islands, the northern half being variations of diorite—basic, felspathic, and quartzose—together with two small areas of granite. Mr. Parkinson retains the name hornblende gabbro, which was employed by Messrs. Hill and Bonney in their paper on Guernsey in 1884 (Quart. Journ., vol. xl, pp. 410 and 425), but dropped after their work in 1910 (Quart. Journ., vol. lxviii, pp. 32–7) as they found it impossible to separate precisely the varieties of diorite, though convinced that some of them, at any rate, had once been augitic rocks. Dyke rocks occur in all the islands, and in some mica-traps are rather abundant. These are post-Arenig, and the greenstone, though rather older, is probably the same. Microgranites are also found, some of which seem to be post-Cambrian. The diorites, however, are probably pre-Cambrian, and form a very interesting group of associated rocks. As might be expected from their geographical position, the sedimentary and some of the igneous rocks of these islands are nearly related to those of the adjacent mainland of France, but the hornblende schists and granulites of Sark are often indistinguishable from corresponding rocks at the Lizard.

AUSTRALIAN ANTARCTIC EXPEDITION, 1911–14: SCIENTIFIC REPORTS. Series C, Vol. IV, pt. iii: Brachiopoda. By J. ALLAN THOMSON. With 4 plates and 1 map. June, 1918.

PART I of this memoir gives a systematic description of the Brachiopods obtained by the Australian Antarctic Expedition, preceded by an account of what is known of the spicules of calcite found in the body-wall and other parts, together with some remarks on the punctation of the shell. Sixteen species are described, and are referred to the genera *Crania, Hemithyris, Liothyrella, Amphithyris* (gen. nov.), *Stethothyris, Gyrothyris, Magellania, Terebratella,* and *Macandrevia.*

Part II deals with the geographical distribution of the Brachiopods of the Southern Seas. Twenty geographical districts are recognized in the part of the sea-floor above the 1,000 fathom line, but in half of these no Brachiopods have yet been found, so that future discoveries may necessitate modifications in the conclusions drawn from the distribution of the small number of species at present known. Only one species is common to two of these geographical districts; all the other species are confined to single districts.

The author points out the resemblance between the recent

Brachiopod faunas of these districts and the fossil faunas found in the Upper Tertiary of the neighbouring lands. Thus the recent New Zealand fauna is a diminished representative of the Oamaruian fauna; the recent Australian fauna (excepting the subtropical part on the north-east coast) is a remnant of the Australian Miocene fauna of that continent. The Antarctic recent fauna is least like the Tertiary fauna of that district, owing to the presence of recent northern immigrants (*Macandrevia, Frieleia, Magellania* s.str.). The author concludes that the distribution of the recent brachiopods in the Southern Seas is explained by the ancestral distribution in the Miocene period, and that it calls for no shallow-water connexions between the various southern continents and islands since that date, except perhaps between South America and the Antarctic.

On the other hand, the resemblances between the Oligocene–Miocene faunas of the four regions named indicate the existence at an earlier date of greater means of communication between the lands bordering the Southern Pacific Ocean than exists at the present day.

The genera *Argyrotheca, Amphithyris, Kraussina*, and *Megerlina* are found in the New Zealand and Australian districts, but not in the Antarctic and South American; as these genera occur also in the Indian Ocean and the Mediterranean the author suggests that Australia had former connexions with South Africa and the Mediterranean. Dr. Thomson states that the molluscan faunas of the Patagonian of South America and the Oamaruian of New Zealand give evidence of a much warmer climate than is found at present in these regions. The occurrence of some species and genera of Brachiopods in the Oligocene–Miocene of the Antarctic which are also found in the Patagonian, the Oamaruian, and the "Miocene" of Australia suggests a warmer climate for the Antarctic seas of that period.

The author urges the desirability of further dredging on the submarine banks of the Southern and Pacific Oceans; if these banks are due to the sinking of land masses the remains of coastal faunas should be found on them. The concluding pages of the work give a brief account of the diastrophic history of New Zealand. The map of the Antarctic and Southern Oceans shows the 1,000 and 2,000 fathom contours.

PETROLOGY FOR STUDENTS. By ALFRED HARKER, M.A., LL.D., F.R.S., F.G.S. 5th edition, revised. pp. 300, with 100 figures. Cambridge University Press, 1919. Price 8*s*. 6*d*. net.

DR. HARKER has been enabled during the comparative freedom from the burden of teaching afforded by the War to prepare a fifth and further revised edition of his standard textbook of petrology, which is too well known to require a detailed notice here. Considerable parts of the work have been rewritten, and the results of all important recent work is incorporated. The author has made use of the work of British petrologists since the issue of the fourth edition in 1908, and has found it possible to illustrate most of the important rock-types by examples drawn from home and from the British Empire. Besides new material there is a certain amount of rearrangement, noticeable especially in the chapters on nepheline-syenites and phonolites and in the section devoted to metamorphism. A number of new figures have been added, bringing the total to 100. These are a most useful feature of the book, and it is unfortunate that some of them have been printed off for this edition in a manner that fails to do justice to the beauty of the original drawings. We are glad to observe that Dr. Harker's book is still sold at a price that brings it within the reach of every student, while to the advanced worker it is equally valuable as a work of reference and standard authority on its subject.

PALÆONTOLOGY (INVERTEBRATE). By H. WOODS, M.A., F.R.S. 5th edition. pp. 411, with 173 figures. Cambridge University Press, 1919. Price 12*s.* 6*d.* net.

ALTHOUGH this fifth edition of Mr. Woods's book is apparently smaller than the last, it actually contains 23 more pages and 24 fresh figures. It has been revised throughout, additions and modifications being made in most parts of the work. The section on the Asterozoa has been to a large extent rewritten, so as to bring it into accordance with the recent work of Dr. W. K. Spencer on Palæozoic starfishes. A revised account is given of the distribution of marine mollusca at the present day. In the section devoted to the Trilobites account is taken of the recent work of Walcott on the appendages and of Ruedemann on the median eye. The account of the Malacostraca has been amplified, and the classification of Calman and other recent writers adopted. The work of revision must have been difficult owing to the extensive additions to the literature of almost every group of invertebrates since the appearance of the fourth edition, and the author is to be congratulated on the successful manner in which he has dealt with this. It is to be regretted that enhanced cost of production has made such a considerable increase in the price necessary, since some students of geology may thereby be deterred from buying this indispensable work.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

November 19, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the chair.

The following communication was read: "The Pleistocene Deposits around Cambridge." By Prof. John Edward Marr, Sc.D., F.R.S., V.P.G S.

This paper deals with the deposits in the immediate vicinity of Cambridge, and contains new records of sections, fossils, and implements. It is pointed out that owing to alternating periods of erosion and aggradation, relative height above sea-level is not a trustworthy index of antiquity, and modifications of the classification proposed by W. Penning and A. J. Jukes-Browne are indicated.

The author suggests the following chronological sequence, in descending order :—

		Feet.
1.	Barnwell Station Beds	20
2.	Newer Downing Site Beds	35
3.	Newer Barnwell Village Beds	45
4.	Huntingdon Road Clays	70
5.	Observatory Beds	85
6.	*Corbicula* Gravels (Barnwell village, etc.) . .	30

The figures on the right give the approximate height above sea-level.

It is believed that Nos. 6 and 5 were formed during a period of aggradation, and 4–1 during one of subsequent erosion with minor aggradation ; but it cannot be conclusively proved that 6 and 3 are of different ages, although the deposition of the beds 6 below those of series 3, where they occur together, and the occurrence of *Hippopotamus* and *Belgrandia marginata* with *Corbicula* suggest an early date for these *Corbicula*-bearing beds.

Taking the beds in the order of reputed age, the following observations are noted :—

Chellean implements have been found at low levels at Barnwell and Chesterton, and may belong to beds 1. The Observatory Beds have yielded abundant implements of Chellean, Acheulean, and early Mousterian types, the last-named apparently in deposits later than those containing the two first-named. Unfortunately mollusca and mammalia are very rare in these beds. The Huntingdon Road Clays require further work, as only poor exposures have hitherto been found, and it is not clear that they are newer than the Observatory Beds.

The beds referred to the Newer Barnwell Village Series contain abundant remains of the mammoth, woolly rhinoceros, and fairly numerous horse-bones. Implements associated with them suggest an Upper Palæolithic age.

The Newer Downing Site Beds have yielded a cold molluscan fauna. They are probably somewhat earlier than the Barnwell Station Series, which has furnished a similar molluscan fauna, and also an Arctic flora, the plants of which were identified by the late Mr. Clement Reid. Reindeer occurs in these beds.

The paper is chiefly a record of facts, but it is intended to be preliminary to a detailed survey of the Pleistocene deposits of the Great Ouse Basin, which are so important as throwing light upon the relationship of the Palæolithic beds to the glacial accumulations, and also to the marine beds of March and the Nar Valley.

Appendix I, on the Non-Marine Mollusca, is supplied by A. S. Kennard, F.G.S., and B. B. Woodward, F.L.S., F.G.S.

Lists are given of the non-marine mollusca from the various sections, with their degrees of frequency. These lists are based on examination of old collections and on a large amount of new material. Notes are appended on some of the species, and conclusions as to the ages of the Cambridge gravels are given, based on the molluscan evidence.

Appendix II, on the Implements, is supplied by Miles C. Burkitt, M.A.

GEOLOGISTS' ASSOCIATION.

December 5, 1919.

The following lecture was delivered: "Geological Work on the Western Front." By W. B. R. King, B.A., F.G.S.

A short description was given of the geology of that part of Belgium and France over which military operations were conducted by the British armies between 1915 and the summer of 1918.

It was mainly confined to the lithological divisions and did not deal with the palæontological side of the subject. The main physical features were taken, showing how they are connected with the geological structure.

The effect of the geology and the geological structure on certain questions of military operations were dealt with, notably with regard to water supply and military mining and dug-out construction. Particular attention was paid to the problem of obtaining water from boreholes in the Landenien (Thanet) Sands, the causes and effect of the seasonal variation of water-level in the Chalk, and the problem of the military mines near Messines, Givenchy-les-la-Bassée, and Souchez.

The lecture ended with a description of certain maps which were prepared for the armies in France, and notes on several other problems which had to be dealt with by the geologists attached to General Headquarters.

LIVERPOOL GEOLOGICAL SOCIETY.

November 11, 1919.—W. T. Walker, Esq., B.Sc., F.G.S., President, in the chair.

The following communications were read: "The Contribution of a local Geological Society to a Regional Survey." "Marl and Marling in Cheshire." By William Hewitt, B.Sc.

The idea of a fairly complete systematic survey of a district—comprising its physiographical and geological features, its climatic record, its botanical and zoological population and distribution, its ethnographical and archæological history, its agricultural and industrial conditions and their evolution—as the basis of a carefully planned scheme of development for the district as a whole, has received considerable attention in recent years, largely owing to the persistent advocacy of Professor Patrick Geddes. The recent establishment of a Regional Survey Association for the Liverpool district, initiated by Professor P. M. Roxby, and the progress already made in connexion with the survey of the peninsula of Wirral—the first piece of work undertaken by that Association—is well known, and the object of the first communication was to suggest that the geological section of such a survey was one that might well be taken in hand by a local Geological Society and worked systematically by the Society as a body in accordance with a carefully planned scheme of investigation and record. A list of problems for investigation and record was submitted and elaborated, including: Coast erosion and changes, reclamation of land from the sea, records or indications of changes of relative level of land and sea in geologically recent times, natural drainage systems, existing stone-quarries and brickfields, and distribution of other commercially valuable mineral substances, nature and character of the soil and subsoil, etc.

The second communication served as a practical illustration of the nature of the investigations which might be undertaken, and embodied much useful and interesting information concerning marl and the extensive marling of the land in Cheshire in past days.

Following the reading of the papers, Professor Roxby gave an account of the work which has already been done in Wirral, and exhibited a series of maps on which the information thus far collected has been expressed; after which Professor Boswell, who has been appointed director of the geological and physiographical section of the survey, dealt more particularly with some of the investigations which awaited attention, among which a survey of the soil was one of the most important and pressing.

CORRESPONDENCE.

BRACHIOPOD NOMENCLATURE: *SPIRIFER* AND *SYRINGOTHYRIS*.

Sir,—In my paper on the above subject in the August number of the Geological Magazine, pp. 371–4, the dates of publication of the genus *Spirifer* by Sowerby were left in doubt. Mr. C. Davies Sherborn has kindly informed me that the paper read to the Linnean Society was published in Trans. Linn. Soc., vol. xii, pt. ii, p. 515, in September or October, 1819 (see Trans. Geol. Soc., vol. v, p. 633, under List of Donations). *Min. Conch.*, vol. ii, No. 21, was published in February, 1816 (see Bull. Soc. Vaudoise, 1855). The genus *Spirifer* was therefore first published in 1816, with sole species *Spirifer cuspidatus*, and my argument holds good.

With regard to *Ichthyosaurus*, however, it appears that Flower and Lydekker did not go fully into the matter, for it was proposed by Koenig in 1818, and therefore is not preceded by *Proteosaurus* Home, 1819.

J. Allan Thomson.

Dominion Museum, Wellington, N.Z.
October 3, 1919.

THE SGURR OF EIGG.

Sir,—My attention has been called to this time-honoured controversy by the contributions to the subject by my friends Dr. Harker and Mr. E. B. Bailey.

In 1898 I mapped the Sgurr very carefully on the scale of 6 inches to the mile, and obtained a good deal of evidence that has not yet been published.

For instance, there are pebbles of granite in the Bidein Boidheach conglomerate, granite of a Tertiary type and resembling none of the older granites in Scotland. This certainly suggests that the conglomerate or breccia is of late date and not of pre-dolerite age.

The dolerite sill (if it be a sill at all) at Bidein Boidheach does not turn upwards at the junction, but is cut off abruptly. The basalt dyke at the same place is also cut off, in my opinion. I have never seen any fragmental deposit that could stop a basalt dyke that had pierced through a succession of lavas.

I made many observations of the inclination of the base of the pitchstone, and there is no doubt that rock occupies a very distinct and deeply cut groove in the basalt lavas and dolerite sills. Incidentally I may mention that in my opinion the sills are far fewer than Dr. Harker would suggest.

The bottom breccia at the base of the Sgurr (eastern end) I took to be, as Dr. Harker says, part of the pitchstone, but not intrusive. As I read the evidence, it is the brecciated base of the flow over which the rest flowed. It has picked up fragments of basalt, sandstone, wood, etc., and rolled along under the main mass. A coating of glass round basalt fragments is quite to be expected. I have never seen any intrusion that acted in quite the same way, though I have seen igneous breccias formed at the edges of intrusions.

I left Eigg quite convinced of the general accuracy of Sir Archibald Geikie's theory, and nothing that I have read since has induced me to change my opinion.

Dr. Harker's theory rests on too many theoretical considerations; Sir Archibald Geikie's theory, especially as championed by Mr. Bailey, rests chiefly on field evidence. In such cases, from a long and very varied experience of field-work all over the world, I naturally give the greatest weight to field evidence, and though I do not wish to belittle any of the microscopic evidence that Dr. Harker has brought forward nor to disregard any of the arguments he has advanced, I cannot accept his theory.

E. H. Cunningham-Craig.

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All Communications for the EDITOR should be addressed to
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EDITED BY

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

AND

R. H. RASTALL, M.A.

FEBRUARY, 1920.

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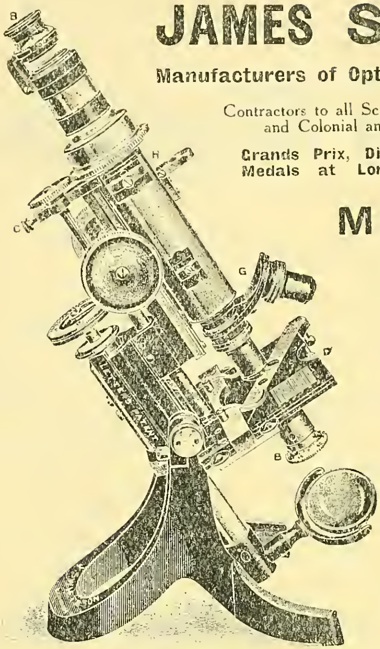
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THE

GEOLOGICAL MAGAZINE

VOLUME LVII.

No. II.—FEBRUARY, 1920.

EDITORIAL NOTES.

THE Editors have been much gratified by the kind response that they have received to their appeal for the support of geologists both at home and abroad in their endeavour to secure the continuance of the GEOLOGICAL MAGAZINE. Numerous letters have come to hand from all quarters promising valuable assistance, both moral and material, in their campaign against the adverse conditions that at one time threatened the very existence of the Magazine. The Editors felt sure from the beginning that it was only necessary to inform their friends of the critical situation in order to enlist their help, and this confidence has been abundantly justified, so much so that it is now possible to look forward to the future with some degree of assurance, although it is still clear that the margin of safety is not yet adequate to ensure against difficulties arising from a further possible increase in the cost of production. The strictest economy will still be essential in every way. It may perhaps clear the air and avoid any possible misunderstanding if it is generally understood that the editorship is now a labour of love, at any rate in the sense that it is not remunerated. It is hoped that this condition is only temporary, and that it may in a while be possible to revert to the former state of affairs, but at present even a small editorial salary is inconsistent with the continuance of the Magazine. It is, of course, impossible to cater with equal success for all tastes, and the Editors can only do what they think will give most satisfaction to the majority of readers. Although a certain amount of criticism has been received, yet this is far outweighed by the mass of favourable comment coming from many quarters, for which the Editors are duly grateful.

* * * * *

A SPECIALLY pleasing feature has been the active support obtained from sources outside this country; from the British Dominions overseas, and especially from the United States of America. Kindly letters have come to hand from South Africa, New Zealand, and many other countries where geology flourishes. But the best news of all comes from America. On New Year's Day a cable was received from Boston, stating that the Geological Society of America has guaranteed to find forty new subscribers for the present year. This great assistance we owe largely to the efforts of our kind friends and contributors, Dr. J. M. Clarke, of Albany, and Mr. P. E. Raymond, of Harvard, to whom we hereby tender our hearty thanks. It is events of this kind that encourage us to carry on in the hope of promoting that worldwide exchange of geological thought which we have so much at heart, and which we firmly believe to be so beneficial to the science of geology in general and to individual workers in particular.

* * * * *

The Council of the Geological Society has this year awarded its annual Medals and Funds as follows: The Wollaston Medal to Professor Baron G. J. de Geer, of Stockholm, whose work is so well known to all geologists, and especially to glacialists, as to need no further reference here; the Murchison Medal to Mrs. Shakespear, formerly Miss E. M. Wood, the collaborator with Miss G. L. Elles in their great work on graptolites and the author of many papers on Palæozoic stratigraphy; the Lyell Medal to Mr. E. Greenly, whose long awaited memoir on Anglesey we hope will soon see the light; the Wollaston Fund to Captain W. B. R. King, late of the Geological Survey and now Assistant to the Woodwardian Professor at Cambridge, whose geological work on the Western front has lately been mentioned in our pages; the Murchison Fund to Dr. D. Woolacott, a recent and valued contributor to this Magazine, who has specialized on the geology of North-Eastern England; while the Lyell Fund is divided between Dr. J. D. Falconer and Mr. E. S. Pinfold, who have in recent years been working in Nigeria and India respectively.

* * * * *

At a recent sitting of the Non-Ferrous Mining Committee of the Board of Trade some interesting evidence was given with regard to the present position and prospects of lead and zinc mining in the Halkyn district of Flintshire. Most of the mines in the district have now been worked almost down to the level of the existing drainage tunnel, and working below this is obviously impossible, owing to the great volumes of water running through the Carboniferous Limestone, as the writer can testify from recent experience underground in that region. A large scheme is on foot for a drainage tunnel at or near sea-level, which would unwater a considerable additional depth of rich veins. Such an undertaking is as a rule too large for any single company to tackle successfully, but there seems to be no possible doubt that judicious co-operation assisted by a subsidy from public funds would result in great developments in this district, where the veins are undoubtedly very rich and mining in the past has been very successful. The recent rise in the price of the metals concerned foreshadows a promising future for this interesting area, if the difficulties alluded to above can be successfully overcome, and there seems to be every possible reason why a far-sighted and public-spirited policy should here be put into action. It seems possible that the great resources of underground water in Flintshire might even be profitably utilized for the generation of electric power to supply the rapidly growing industrial districts along the estuary of the Dee, and so assist to conserve the coal resources of that part of the country.

* * * * *

At a special meeting of the Council of the Mineralogical Society on January 20 it was resolved to commence immediately the publication of a series of Mineralogical Abstracts. These will be issued as a separately paged appendix with future numbers of the *Mineralogical Magazine*, which it is hoped will be published at more frequent intervals. It is also proposed to place the Abstracts on sale separately. The name of the author, full title, as in the original, and an intelligible reference will be quoted, thus serving at the same time as a bibliography or catalogue of scientific papers and books, which will be fully indexed. The Abstracts themselves will be brief (200–250 words), though giving as much detail of original matter as possible, but in the case of longer papers and books no more than the nature of the contents can be indicated. It is hoped to include not only all papers and books dealing with purely scientific mineralogy and crystallography, but also to call attention to matters of mineralogical interest in original papers bearing more on petrology, ore-deposits, and economics. The Mineralogical Society being only a small society, the work of abstracting must be carried on by voluntary helpers. It is proposed to allot groups to workers interested in different branches, and to collect their abstracts in batches under suitable headings, e.g. New Minerals, Crystal-structure and X-rays, Optical Methods in Crystallography, Rock-forming Minerals, Meteorites, Ore-deposits, etc. Anybody willing to co-operate in this work, or desirous of joining the Society, will be welcomed. Authors can assist in the search for material suitable for abstraction by sending reprints of their papers to the editor, L. J. Spencer, Natural History Museum, S.W. 7.

* * * * *

The Council of the Geological Society of London has made the following recommendations for the election of officers for the ensuing year: President, Mr. R. D. Oldham; Vice-Presidents, Professor E. J. Garwood, Mr. G. W. Lamplugh, Col. H. G. Lyons, and Professor J. E. Marr. No changes are proposed in the offices of Secretary and Treasurer. The following members of the Council retire: Sir J. Cadman, Dr. C. W. Andrews, Dr. G. Hickling, Sir J. J. H. Teall, and Mr. S. H. Warren. The following are recommended for election as ordinary members of the Council: Professor W. S. Boulton, Professor O. T. Jones, Mr. R. G. Carruthers, Capt. W. B. R. King, and Lieut.-Col. W. Campbell Smith.

ORIGINAL ARTICLES.

On an Inverted Mass of Upper Cretaceous Strata near Leighton Buzzard, Bedfordshire; and on an Overlap of the Upper Gault in that Neighbourhood.

By F. L. Kitchin, M.A., Ph.D., and J. Pringle, F.G.S.

(*Continued from p. 15.*)

B. Comparison with other Sections in the District.

I. *Sections near Leighton Buzzard.*

We owe to Mr. Lamplugh a description of the lowest beds of the Gault and their junction with the Lower Greensand, as seen in sand-pits on the south side of Leighton Buzzard.[1] Mr. Lamplugh proved the presence of the fauna of the *mammillatus* zone and found that the fossils preserved in the gritty phosphatic nodules of the lowest bed above the false-bedded sands include *Douvilleiceras mammillatum* (Schloth.) and the characteristic *Desmoceras* usually associated with it.[2]

In May of last year an excellent section, comprising Lower Greensand and Lower Gault, was shown in a sand-pit (Mr. Webster's) about 200 yards south of Billington Crossing (No. 1) on the Leighton Buzzard–Dunstable railway (L. & N.W.R.). This old excavation was reopened at the end of 1918 and has now been abandoned. At the time of our visits the beds exposed were as follows:—

		ft.	in.
	Soil	1	0
Gault with *interruptus* fauna	Greenish-grey stiff lumpy clay with a few smooth skinned nodules. Numerous fragments of ammonites of the *interruptus*-type occur mainly in the form of casts . . . . about	4	0
	Brownish sandy clay with streaks of glauconite .	1–2	0
	Thin band of dark-grey clay		2–3
Passage-bed to Gault, with *tardefurcata* fauna	Dark-brown well-bedded sandy clay with numerous rounded quartz-grains and pebbles. Pale-coated dark gritty phosphatic nodules of irregular shape (up to 6 inches in diameter), their surface studded with quartz-grains, occur sporadically throughout . . . . about	4	0
Lower Greensand	Dirty brownish-white false-bedded sand with bands and masses of iron-grit in lowest 5 feet. Numerous thin brown rusty streaks occur parallel to bedding-planes; the sand paler in colour at the top . . . . . seen to	9	0

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[1] G. W. Lamplugh, "Report of an Excursion to Leighton Buzzard": Proc. Geol. Assoc., vol. xxvi, pt. v, 1915, p. 310.

[2] Specimens of the *Desmoceras* were submitted to one of the present writers and were identified by him; but he is not responsible for the name under which they were cited in Mr. Lamplugh's report (op. cit., p. 310). For a further account of the species see A. J. Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. i, "The Gault and Upper Greensand of England" (Mem. Geol. Surv.), 1900, p. 443; also G. W. Lamplugh & F. L. Kitchin, *On the Mesozoic Rocks in some of the Coal Explorations in Kent* (Mem. Geol. Surv.), 1911, p. 100.

A similar but less complete section of the beds overlying the Lower Greensand is to be seen at the eastern end of the sand-pit on the north side of the level-crossing (No. 2).

The following are some of the fossils collected by us from the *tardefurcata* bed of these two pits: all, with the exception of a single specimen of the *Desmoceras*, found half-way up in the bed, were encased in the rough-coated nodules.

Terebratula sp.
Exogyra conica ? (J. Sow.).
Panopea sp.
Pecten (*Syncyclonema*) *orbicularis* J. Sow.
P. (*Neithia*) sp.
Desmoceras aff. *beudanti* (Brongn.).
Douvilleiceras mammillatum (Schloth.).
Leymeriella regularis (Brug.).
L. tardefurcata (d'Orb.).
Sonneratia dutempleana (d'Orb.).

The most significant of these fossils are the species of *Leymeriella* and *Sonneratia*, which have hitherto not been recorded from any locality in this country. These or other species of the *Leymeriella*-fauna[1] mark a definite zonal subdivision in certain districts on the Continent (Ardennes, South-Eastern France, and Brunswick),[2] occurring in association with *Douvilleiceras mammillatum*, but marking a time-period prior to the introduction of the *interruptus*-fauna. The *mammillatus* bed at Folkestone, as in the neighbouring part of France, contains elements of the *interruptus*-fauna, but no specimen of *Leymeriella* has been recorded from it. It therefore seems highly probable that the zonal representation is imperfect in that region, and we may conclude that the passage from Lower Greensand to Gault is more clearly demonstrated at Leighton Buzzard than at any exposure in England hitherto described. We think it not unlikely that the sandy basement-bed of the Gault at West Dereham, Norfolk,[3] would also yield the *tardefurcata*-fauna if it were thoroughly searched. Jukes-Browne's description of the lowest Gault at Clophill,[4] east of Ampthill, conveys the same suggestion.

It should be noted that no specimen of *Belemnites minimus* or of any ammonite of the *interruptus*-type was found in the *tardefurcata* bed, while in the higher part of the section not one of

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[1] For figures and descriptions see C. Jacob, "Étude sur quelques Ammonites du Crétacé Moyen": Mém. Soc. Géol. France, Paléontologie, No. 38, 1907, pp. 53–8, pls. vii, viii.

[2] C. Jacob, "Études Paléontologiques et Stratigraphiques sur la Partie Moyenne des Terrains Crétacés dans les Alpes Françaises et les Régions voisines": Trav. Laboratoire de Géologie de la Faculté des Sciences de l'Université de Grenoble, vol. viii, fasc. ii, 1908, pp. 296–7. W. Kilian, *Lethea Geognostica*, II. Das Mesozoicum, Bd. iii, Abth. i, "Unterkreide," Lief. i, 1907, p. 62. G. Müller, "Beitrag zur Kenntniss der Unteren Kreide im Herzogthum Braunschweig": Jahrb. k. preuss. geol. Landesanst. für 1895, vol. xvi, p. 110, Berlin, 1896.

[3] J. J. H. Teall, "The Potton and Wicken Phosphatic Deposits" (Sedgwick Prize Essay), 1875, pp. 20–2. A. J. Jukes-Browne, *The Cretaceous Rocks of Britain*, vol. i, "The Gault and Upper Greensand of England" (Mem. Geol. Surv.), 1900, p. 297.

[4] Op. cit., p. 285.

the ammonites recorded in the above list was seen. Many ammonites were found in this upper bed of clay, chiefly in the form of fragmentary casts; but every one was a *Hoplites* of the *interruptus*-type. Several species are represented, and it is unnecessary for our present purpose to attempt to name them critically. They display no greater diversity than is seen among a number of distinct species determined alike as *Hoplites interruptus* (Brongn.) in the chief public collections. *Belemnites minimus* List. also occurred, and among the few imperfect lamellibranchs found we recognized *Plicatula gurgitis* Pict. & Roux.

We believe that an almost complete passage from Lower Greensand to Lower Gault is shown here. Although the dividing-line between the Lower Greensand and the *tardefurcata* bed is clearly marked, and has been described by Mr. Lamplugh as a "sharp junction", there is no appearance of any considerable break in the series. The contrast lies in the change from the cross-bedded character of the sands below to the horizontal bedding, with accession of the clay-constituent, in the overlying bed. This might be interpreted as merely proclaiming a somewhat rapid transition to more tranquil conditions of sedimentation. At Miletree Farm (No. 8), however, the *tardefurcata* bed with gritty phosphatic nodules is separated from the top of the cross-bedded Lower Greensand by a 6 ft. bed of horizontally stratified fine sand of distinctive character, indicating that there is probably a true stratal break at Webster's Pit, though not one of any considerable magnitude.

A comparison between the section at Webster's Pit and that in Harris's Pit at Shenley Hill thus demonstrates how strikingly they are contrasted in all essential particulars. In the neighbourhood of Billington Crossing there is no sign of the beds C to G of Shenley Hill; that is, the brachiopod bed, the basal Upper Gault, the ironstone-bands, and the impure sands overlying the "silver-sands". The lithological development of the Gault Clay in the two sections is so different as alone to cast doubt on the identity of these beds; while a study of the fossils proves that no correlation of any part of the Gault in the two localities is possible.

II. *Sections near Shenley Hill.*

Sections in the neighbourhood of Shenley Hill show that there, also, the relations between the Lower Greensand and the Gault are different from those seen at Billington Crossing.[1] Only at one locality, a pit on the north side of Miletree Farm (No. 8), have we found the *tardefurcata* bed above the false-bedded Lower Greensand. In the same remarkable section the Upper Gault is seen to rest discordantly upon these earlier beds. Farther to the west, the Upper Gault,

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[1] The difference was remarked upon by Jukes-Browne, who pointed out that south of Leighton Buzzard there is a gradual passage down to Lower Greensand, while in this more northerly development there is not. *The Cretaceous Rocks of Britain*, vol. i, "The Gault and Upper Greensand of England" (Mem. Geol. Surv.), 1900, p. 284.

with a well-marked basement-bed, overlaps on to the current-bedded Lower Greensand.

At the present time development is proceeding actively in the sand-workings of this neighbourhood. New openings are being made and progress in excavation is so quick, both in these and in older pits, that new geological information is made available within a short interval of time. The stratigraphical relationships show rapid lateral changes in this vicinity, owing to the Upper Gault transgression and the active erosion which accompanied it. For these reasons the detailed description of a section studied on a given date may not be strictly applicable in the same pit at a later time.

The following was the section seen in October last towards the southern end of the western face in the pit north of Miletree Farm (No. 8):—

		ft.	in.
	Soil and subsoil	3	0
Passage-beds to Gault, with *tardefurcata* nodules.	Brown and mottled sand with thin hardened calcareous streaks along the bedding; the top 6 inches with many pebbles and rounded grit-grains	3	0
	Crowded flat pale-brown horizontally disposed claystone-nodules, containing minute traces of plants and with external films of secondary limonite		6
	Pale-brown sand with rounded quartz-grains and small pebbles, darker in hue in lowest 2 feet; and with a few sporadic, partly indurated sand-nodules and pale-coated dark gritty phosphatic nodules	4	6
Lower Greensand.	Horizontally bedded fine sands with streaks of black clayey sand, dirty "silver-sand", and thin layers of brown iron-stained sand; lignite associated with the black clayey layers; a few inconstant brown ferruginous indurated courses, 2 inches in thickness	6	0
	False-bedded white sands, iron-stained in places, with occasional scraps of lignite; seen to	18	0

The *tardefurcata* bed is here separated from the false-bedded Lower Greensand by a well-characterized 6 ft. deposit of sand, many layers of which are peculiar by reason of their very fine smooth texture and by the alternation of lighter streaks and dark carbonaceous and clayey streaks. We recognized at once that this bed shows a striking resemblance to the fine, similarly impure, sand of bed G in Harris's Pit.

The overlying stratum may be correlated with the *tardefurcata* bed of Billington Crossing. We could not break open a sufficient number of the nodules to enable us to obtain any of the characteristic ammonites, although a few other fossils were found;[1] but the nodules themselves are identical in character with those found at Webster's

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[1] While working at Billington Crossing we estimated that the yield of ammonite specimens in relation to the number of nodules broken open is considerably less than 1 per cent.

Pit and in the exposure near to it where this bed was seen. They have the same pale exteriors, roughened by protruding quartz-grains, and the fractured surfaces of their interior parts show the same dark, compact, hard ground-mass of phosphatic material enclosing rounded quartz-grains and rusty specks. The overlying 6 in. bed of claystone-nodules and the 3 ft. bed of sand at the top of the section are developments not seen at Billington Crossing. The series above the false-bedded sands is thus a fuller one at Miletree Farm, but the variation shown is just what might be expected to occur under the conditions which prevailed prior to the deposition of the deeper-water *interruptus* clay.

Towards the northern end of the western face in the same pit (No. 8) the whole of the above series of horizontal sandy beds becomes cut off obliquely by a mass of Upper Gault, showing a well-marked basement-bed sloping down towards the north (Fig. 3). The following is the section as examined at an easily accessible spot, indicated by an arrow on the figure :—

		ft.	in.
	Soil with a few subangular flints . . .		6
Upper Gault Clay.	Lowest clay of Upper Gault, containing small white calcareous nodules (up to 1 inch in diameter)	4	0
Basal bed of Upper Gault.	Impure yellowish-brown earthy sand with some admixture of clay and many rounded quartz-pebbles (up to ½ in. in diameter), and with some white nodules as in clay above ; also brecciated fragments of ironstone and smooth rounded hollow pebbles of ironstone ; an undulating 2 in. limonite ironstone-band (of secondary origin) at base and a similar band at and near the top, the two often broken and dislocated, sometimes approaching each other and becoming confluent ; also thin, irregular interlacing branches of tabular ironstone within the bed ; varying from 4 inches to	1	4
	its undulating lower surface resting unconformably on the tardefurcata bed and underlying sands, as seen in previously described section in the same pit.		

While the original constituents of the basement-bed of the Upper Gault include angular and subangular fragments of limonitic ironstone and many worn hollow pebbles of ironstone, mostly hæmatitic, the thin tabular limonite-bands are evidently of later introduction. They show dislocation and contortion, due to movements in the bed subsequent to their formation.

When traced towards the north within this pit the Upper Gault eventually cuts across lower and lower strata, until it comes in contact with the current-bedded sands at the bottom of the pit. Where this relation is shown, as in the northern face of the pit, the clay above the basement-bed is present to a thickness of about 8 feet, the slope of the ground-surface reducing what would otherwise have been a thicker mass of this clay. The basement-bed and the clay above, which dip towards the east in this face of the pit, are relatively unfossiliferous. The fact that they are both characterized by conspicuous small white nodules (white throughout) is a point to be specially noted, since, owing to the rarity of fossils, the presence of these nodules is helpful in identifying these beds in other sections. *Kingena lima* (Defr.) and a few poorly preserved remains of other brachiopods were found by us in the basement-bed here, but only *Belemnites minimus* List. was seen in the clay above. The characters of the clay, which are constant wherever these beds occur around Shenley Hill, will be noted below in our account of a section in the abandoned Garside's Pit (No. 4), adjacent to Harris's Pit.

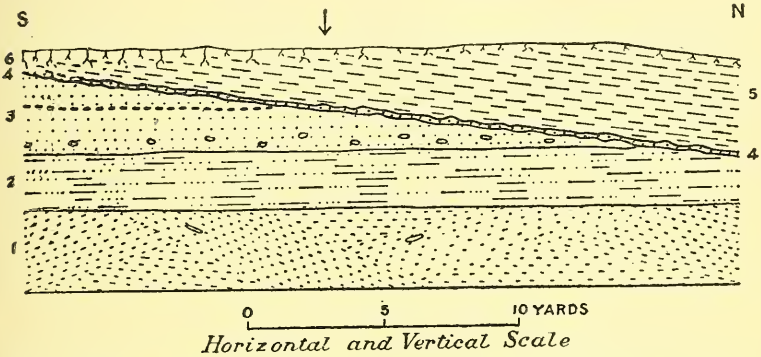

Fig. 3.—Diagram of the section in the western face of the sand-pit on the north side of Miletree Farm (No. 8).

6. Soil.
5. Upper Gault Clay.
4. Basement-bed of Upper Gault, coarse material with thin bands of secondary ironstone; resting unconformably on the Lower Greensand and Passage-bed.
3. Passage-bed between Lower Greensand and Lower Gault; of *tardefurcata*-age. A few dark phosphatic nodules and some partly indurated sand-nodules occur scattered in the lower portion; there is a line of claystone nodules above the middle.
2. Horizontally bedded Lower Greensand; fine sand with clayey and carbonaceous layers.
1. False-bedded Lower Greensand, not all shown in the Figure.

The age of the clay cannot be determined at Miletree Farm, where its higher and more fossiliferous part is not present. Information obtained at a section where a fuller development of it is displayed (No. 9) shows that it must be ascribed to the Upper Gault. We have nowhere seen any exclusively Lower Gault fossil in it.

The relatively steep north-easterly dip of the clay and basement bed shown on the north side of Miletree Farm is probably of quite local significance, and is due to the fact that these beds rest on an eroded slope of older strata. The occurrence of a rapid lateral change is shown in the pit situated just south of the farm (No. 7), where the relations of the Upper Gault to the underlying beds are indeed surprisingly different. The 6 ft. bed of fine horizontally bedded Lower Greensand and the 8 ft. bed of passage strata overlying it, seen north of the farm, are absent. In the northern face of this southern pit the Upper Gault rests directly upon the false-bedded Lower Greensand. The peculiar basement-bed of the northern pit is present here, but is separated from the underlying current-bedded sands by one foot or so of obscurely bedded rather dingy grey-brown pebbly and gritty sand with polished grains. This contains some of the characteristic phosphatic nodules of the *tardefurcata* bed, seen in place north of the farm. This thin deposit of sand is evidently a product of the denudation of the *tardefurcata* bed (see Fig. 3), which is situated at a higher level. Its position just above the false-bedded sands, as well as the presence in it of the small white nodules which characterize the basal beds of the Upper Gault here, shows that it belongs to the period of the transgression. The clay above the basement-bed is present to the extent of 4 feet in thickness. It contains the small white nodules, but differs from the corresponding clay seen north of the farm by the presence in its lower part of numerous highly polished quartz-pebbles, up to half an inch in diameter.

At the west side of pit No. 7, the lowest clay of the Upper Gault is overlain by some imperfectly bedded, crumbled, grey clay, which is met with in other sections about to be described. At the southern end of the pit the false-bedded Lower Greensand crops out at the surface, and no Gault is present. The grey clay just mentioned, which overlies the lowest 4 feet of Upper Gault Clay, is of a peculiar type and is readily recognizable in the other sections where it has been seen. It is a soft clay without any well-defined bedding-planes, and is made up of innumerable small pellets, which are for the most part somewhat angular in shape. It might be termed a finely brecciated clay. We think it most probable that the material of which it is composed is the redeposited débris resulting from the denudation of some previously formed, well-consolidated clay. It is relatively unfossiliferous, and appears to contain no ammonites. Here and there it contains small pockets of glauconite, with some of which a few specimens of *Belemnites minimus* List. are associated.

It is evident that at Miletree Farm the upper beds of the Lower Greensand, with the passage-beds at the top, were subjected to erosion under the action of strong currents. They stood up here on the sea-floor as a bank of consolidated, though soft, horizontal strata, the sloping sides of which were being planed away. While the fine, lighter material of the 6 ft. bed of sand underlying the *tardefurcata* bed would, under such conditions, be swept away by currents, some of the nodules and heavier sandy materials of the *tardefurcata* bed found their way down the slope and, as a residue of the local denudation, formed a constituent of the basal deposit of the Upper Gault. An almost identical section, showing the re-arranged sand 1 foot thick (with nodules from the *tardefurcata* bed) at the base of the Upper Gault, resting immediately upon the false-bedded Lower Greensand, is situated in an opening recently made just north of Sandpit Cottages (No. 10). In a neighbouring abandoned working 200 yards north-west of Sandpit Cottages and about 200 yards N.N.E. of Harris's Pit (No. 6), the thin sand-bed with derived nodules is not present at the base of the Upper Gault; the basal bed of mixed composition rests directly on the false-bedded Lower Greensand.

In the large abandoned Garside's Pit, the section at the present southern face (No. 4), at a point about 150 yards S.S.E. of Harris's Pit, is as follows:—

		ft.	in.
	Soil and Drift	1–3	0
Upper Gault Clay.	Crumbled or finely brecciated grey clay, imperfectly bedded, with small brown-skinned and black nodules (up to 1 inch in diameter), and occasional small pockets of glauconite; *Belemnites minimus* found throughout, but abundant near top; small *Inoceramus concentricus* rare; no other fossils seen . . . about	6	0
	Grey and brownish clay, better laminated than the above, with small white calcareous nodules (up to 1 inch in diameter); only *Belemnites minimus* seen; the bottom 1–4 inches stained reddish . . . . . . about	4	0
	resting conformably upon		
Basal bed of Upper Gault.	Clayey yellow and greenish impure sand with much brecciated material, principally fragments of ironstone (up to 3 inches in diameter); the bed has greenish sandy streaks and contains the same kind of white nodules as in bed above .		8–15
	Hard limonitic and partly vitreous iron-grit, forming a continuous band		2–3
	marking unconformable junction with		
Lower Greensand.	False-bedded sands with large irregular indurated masses of iron-grit towards upper part and at top, sometimes confluent with the iron-grit layer above; sands stained bright orange and reddish-brown below . . seen to about	15	0

The lateral variation in the current-bedded sands of the Lower Greensand, both in respect to induration and colour, is so rapid and frequent throughout the district that there need be no hesitation in correlating the upper part of the sands here with the corresponding purer sands at the neighbouring Harris's Pit. When we come to consider the overlying strata, a comparison between these two sections shows that the sandy beds F and G of Mr. Lamplugh's table of strata at Harris's Pit are unrepresented in the series described above. The lenticles of brachiopod-limestone of bed D are also missing here, just as in all the other sections already described. The peculiar basal bed of the Upper Gault, with possibly an occasional trace of the clay lying conformably upon it, supplies the one connecting link. The 18 ft. mass of inverted *rostratus* Gault at Harris's Pit is entirely unrepresented in the above section.

It is necessary to look further before the local correlation of the section in Harris's Pit can be completed. In a long-abandoned pit situated at about 900 yards north-west of that locality and some 300 yards north of Shenley House (No. 9), the Upper Gault Clay is present to a thickness of about 20 feet. Here the lowest beds, as above described in the section at Garside's Pit, were found in similar development overlying the indurated top of the current-bedded Lower Greensand; thus, a basal bed consisting of yellowish-brown and greenish clayey sand with some pebbles (and with ironstone courses), here less than a foot in thickness; the clay above it containing white nodules, red-stained at its base; and the succeeding crumbled and imperfectly bedded grey clay. Above the lowest 8 feet of clay the section is entirely obscured by slips, but at a distance of about 15 feet above the basal bed a pale marly clay with blocky fracture yielded numerous fossils. These include abundant specimens of *Schloenbachia varicosa* (J. de C. Sow.) and a well-keeled *Schloenbachia* similar to one found near the top at Harris's Pit; a *Hoplites* showing a smooth stage in an *auritus*-like stock; another species of the *splendens* type (in the broad sense); *Inoceramus concentricus* Park., and numerous large examples of *Inoceramus sulcatus* Park. This assemblage indicates a position corresponding with Bed IX of Price at Folkestone, and with the clay showing similar lithological and faunal characters at the top of Harris's Pit.

Since the Gault below this fossiliferous bed, at the locality just described, shows such a marked contrast in all its characters to the beds now in corresponding position at Harris's Pit, there are no grounds for correlating them. If the mass of Gault in Harris's Pit were in a normal position this contrast would be difficult to explain. Since we have shown it to be inverted the explanation is simple. The beds there below the clay containing *Inoceramus sulcatus* and *Schloenbachia varicosa* represent a still higher part of the series, of which a portion, only a few feet thick, is present at the top of the section north of Shenley House.

We infer that the Gault *in situ* at Shenley Hill was originally some 40 feet thick at the most; and we consider that the presence of the fauna of Bed IX of Folkestone such a short distance up in the series makes it certain that only the Upper Gault is represented here. This reading of the facts is supported by the ascertained thickness of the formation where it is fully developed farther to the south, even when allowance is made for a general thickening of the sediments in that direction.

The evidence thus shows that the date of the overlap may well coincide approximately with that of the Middle Junction Bed (VIII) at Folkestone. The character of the lowest bed is such as would result from its formation upon a sandy bottom in shallow water under the action of relatively strong currents. The transgression would imply a deepening of the sea-floor, so that these coarser sediments soon gave place to the succeeding clay. Locally, as we have noted at one of the pits at Miletree Farm, the clay immediately above the bottom bed contains pebbles, a sign of continued current-action at that spot. Evidence for the existence of an overlap of *interruptus* or later date has been referred to by Dr. A. Morley Davies,[1] while Professor Kilian has pointed out the widespread character of the transgressive movements proved to have occurred in Upper Gault time.[2]

Another section in this neighbourhood is less easy to interpret. This is the brick-pit, situated 1,100 yards to the southward of Harris's Pit (No. 3), from which Jukes-Browne recorded a number of Upper Gault and Lower Gault fossils.[3] There was at one time an exposure here showing 10 feet of clay with a seam of nodules about the middle, from which the fossils were said to have been obtained. This pit has long been disused and is now so overgrown and flooded as to give no information. Mr. Lamplugh used Jukes-Browne's account of this exposure in support of the contention that the clay at Harris's Pit above the brachiopod-bed is of Lower Gault age. Indeed, this seems to have been the only item of evidence which he was able to bring forward as the basis of the following important statement: "We must therefore conclude that the overlying clay in the sand-pit sections represents Lower Gault, and that the fauna of the calcareous masses is of earlier date." [4]

Now it is clear that if the fossils recorded in Jukes-Browne's list were correctly identified, the nodule-bed in which they occurred does not belong to the Lower Gault; it must be of *rostratus* age. If the Lower Gault fossils truly came from the same bed of nodules they must have been derived; if they did not come from that stratum, then it is conceivable that beds of *interruptus*-age are present at this locality, overlain by the unconformable *rostratus* Gault. Yet the knowledge gained from the sections already described renders it improbable that a 10 ft. section would include both these faunas. No nodule bed similar to that described by Jukes-Browne has been seen in any of the sections examined by us, and we are unable to test the value of his record. It is possible that the bed is present in the concealed part of the section in the Upper Gault 300 yards north of Shenley House (No. 9); the character of the fossils recorded by Jukes-Browne is quite in keeping with such a position, corresponding with Bed IX at Folkestone.

The examination of the undisturbed Gault east and west of Shenley Hill shows that the higher beds of the Upper Gault, which constitutes the main mass of the hill, stand up as an outlier, isolated

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[1] A. M. Davies & J. Pringle, "On two deep Borings at Calvert Station (North Buckinghamshire) and on the Palæozoic Floor north of the Thames": Quart. Journ. Geol. Soc., vol. lxix, pt. ii, 1913, p. 338.

[2] W. Kilian, *Lethea Geognostica*, II. Das Mesozoicum, Bd. iii, Abth. i, "Unterkreide," Lief. i, 1907, pp. 61–125.

[3] A. J. Jukes-Browne, op. cit., 1900, p. 285.

[4] G. W. Lamplugh & J. F. Walker, op. cit., 1903, p. 246.

from the general outcrop of Gault to the east and south-east. In pre-Glacial times the high ground must have been capped by some remnants of the basal Cenomanian bed, as shown by the fossiliferous lenticles preserved at Harris's Pit beneath the inverted mass of *rostratus* Gault.

From the information obtained from the sections above dealt with, as well as from Mr. Lamplugh's published records showing the former occurrence of the brachiopod-lenticles (bed D) in parts of Chance's Pit and Garside's Pit, we can form some idea as to the original size of the overturned mass of strata. A great part of it has been destroyed in the course of the excavations, so that at the present time the remnant is only accessible for study at Harris's Pit. It may be roughly estimated that the mass formerly showed a north and south extension of about 250 yards. The position of its original eastern boundary is more uncertain, but was probably about 150–200 yards distant from the present working face at Harris's Pit (see Fig. 1). It is impossible to say how much further to the west the limit of the mass in that direction might be proved to occur if excavation were to be continued. It is probable that its westerly margin will not be reached in Harris's Pit, a sand-working situated in the slope of the hill with a thickening cover of clay. But the purely local character of the inverted mass has already been sufficiently demonstrated.

(*To be concluded.*)

On the Quartzite Pebbles of the Oldhaven (Blackheath) Beds of the Southern Part of the London Basin.

By Herbert Arthur Baker, M.Sc., F.G.S.

(PLATE I.)

It is common knowledge to all geologists interested in the Lower Eocenes of the southern part of the London Basin that, in the Oldhaven (Blackheath) Pebble Beds, pebbles of a brown quartzite are often to be found on searching amongst the rounded flints of which these beds are so largely composed. When geological parties visit sections exposing the pebble-beds of the Lower London Tertiaries, the search for these quartzites usually constitutes one of the items of the field-work to be done. A considerable number of these pebbles must, by this time, have been collected, but, although their occurrence has given rise to a good deal of discussion and speculation, nobody appears, so far, to have undertaken a systematic examination of their characters and petrological affinities. The view has been propounded that the study of these pebbles would throw light on the question of the source of the material composing the Lower London Tertiary beds. In dealing with the latter question, the difficulty confronting the geologist is that since the pebbles of the Oldhaven Beds consist (except for the quartzites) entirely of rolled flints, and since, where pebble-beds occur in other of the component members of the Lower London Tertiaries, they are always composed of flints, it is naturally inferred that the Chalk was denuded to furnish the material for these strata, but it is obvious that the Chalk alone could not have supplied the arenaceous and argillaceous material composing them. The hope has therefore lingered in the minds of geologists that, sooner or later, the parent-mass of rock from which these quartzites were derived would be located, and evidence concerning the source of the material of the Lower Eocenes be thereby gained.

Dr. G. J. Hinde, in the course of a paper on the Blackheath Pebble Beds of the Addington Hills,[1] referred to these quartzites as follows: "The only exception to the prevalent flint-pebbles which came under my notice were some cake-shaped pebbles of a light-grey quartzite, in form and smoothness of surface very much like the flints, from which, indeed, they could hardly be distinguished until they were broken. These quartzites are very hard and fine-grained. They appear to be rare. The largest I found was about 4½ inches across by 2 inches in thickness (110 by 45 mm.). Judging by the character of the rock, they may have been derived from Palæozoic strata, and it is not easy to account for their presence in these Tertiary pebble-beds, associated as they are with Chalk-flint pebbles exclusively. I am not aware that similar pebbles have been previously recorded in the Blackheath or Oldhaven series, but Professor Prestwich has lately stated that large pebbles of white or light-coloured quartzite, now present in the beds of Westleton shingle, may have been derived indirectly from the shingle-beds of the Woolwich and Reading series, where he has occasionally found them, or they may have come from the quartzites of the Palæozoic rocks of the Ardennes."

In the discussion which has centred round these interesting pebbles (based chiefly on the external characters presented by them), opinion has been divided. Whilst some have been inclined to adopt the view of Hinde and Prestwich, quoted above, that these quartzites may have been derived from Palæozoic rocks, others have considered them to be "sarsens". If it be granted that a sarsen is a rock originally associated with, and derived from, Tertiary strata (not necessarily of Upper Eocene age), then the present writer regards these quartzite pebbles as sarsens, but it is not his intention at this juncture to labour the point, or to embark upon a plenary definition of the term "sarsen". It is here proposed simply to consider these pebbles as pebbles occurring in the Oldhaven (Blackheath) Beds.

With regard to their occurrence, these pebbles are certainly rare,

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[1] Hinde, Proc. Geol. Assoc., vol. xi, 1890, p. 467.

but not of such extreme rarity as has been supposed. They are apparently always to be found where the Blackheath Pebble Beds are exposed, if the seeker has succeeded in cultivating the necessary "eye" for their detection, and pursues his search with patient assiduity. The writer has obtained them from the Blackheath Pebble Beds in the neighbourhood of Plumstead Common, and at East Wickham, Bostall Heath, and Eltham. The pits at East Wickham and Bostall Heath have yielded them in considerable number to various workers. Mr. A. L. Leach and Mr. R. H. Chandler have obtained a good many from these two localities. They have also been found at Charlton and Keston. The outliers of the North Downs have yielded them. They have been found at Worms Heath and in the neighbourhood of Caterham. They occur on beaches in the neighbourhood of the outcrop of the Lower London Tertiary beds. The writer has collected them in numbers on the beach near Reculver, not far from Bishopstone Ravine, and also at Shoreham (near Brighton) and at Dovercourt. They do not occur at Pegwell Bay, where the Tertiary cliff-section is in Thanet Beds only.

In external appearance these pebbles bear a fairly close resemblance to pebbles of partially decomposed flint, but they possess certain characteristics which, when well visualized, lead to their ready detection in the field. They vary in size, but are usually not small, and are generally, though not invariably, characterized by a flattened ovoid shape suggestive of their derivation from hardened, tabular masses. They are usually very hard, capable of taking and frequently possessing, a more than ordinary degree of polish. In colour they vary from brown to grey or nearly white, being frequently buff or drab. A common feature is a mottled marking or patchy colour-distribution. Another interesting type sometimes met with exhibits a kind of wavy banding of darker and lighter coloured material, due, apparently, to a tendency towards aggregation of the iron-oxides present in the rock. The texture of the rock, as examined on fractured surfaces with a hand-lens, is usually fine-grained, sometimes markedly so, but there is frequently considerable variation to be seen, often in one and the same specimen. There is often little approach to uniformity, the conversion of the rock from sandstone or grit into quartzite having apparently proceeded irregularly, so that the crystalline appearance of a quartzite is seen only in patches, the remainder of the rock appearing as a fine-grained saccharoidal sandstone. It is this variation in texture owing to the sporadic character of the silicification which frequently imparts a mottled appearance to the external surface of many of the pebbles.

When the rocks are sliced and examined microscopically it is seen that they are not metamorphic rocks at all, in the strict sense of the term. They have not been produced by either contact or regional metamorphism, but fall within the class of rocks resulting from the operation of what has been termed "atmospheric metamorphism". The rocks are really sandstones or grits which have been cemented as the result of a metasomatic change—the addition of fresh silica as a cementing medium. The name "quartzite", as applied to the rocks, is legitimate by virtue of the definition that a quartzite is a rock composed chiefly of quartz grains with the addition of a quartz cement. Yet, in view of the irregular and inconstant character of the cementation the rock may, with equal propriety, be frequently described as sandstone (where the grains are well rounded) or grit (where the grains have preserved their angularity). It is frequently possible, in different parts of the same slice, to apply the names quartzite, sandstone, and grit with equal justification.

In all the slices examined by the writer no evidence of secondary outgrowth from the quartz-grains was to be observed, and there was no sign of optical continuity between the original grains and the secondary silica. The latter was often amorphous, apparently colloidal, and generally dirty with disseminated iron-oxides. Approach to a quartz-mosaic structure was seen only rarely and locally, and was but imperfectly developed. Where observed, the interlocking grains were of small size, and the feature was apparently developed only in the secondary silica. In the examination of the slices the presence of other minerals such as tourmaline, kyanite, staurolite, zircon, rutile, glauconite, felspar, and iron-oxides was noted. With a view to the further examination of these minerals some of the pebbles were crushed, and minerals possessing a specific gravity of more than 2·80 were isolated by the use of Thoulet's (Sonstadt's) solution. It was then seen that the heavy residue was composed essentially of the assemblage of minerals so characteristic of the heavy residues of the Woolwich and Reading Beds. The writer has recently examined a considerable number of heavy residues from these beds, from various localities on the southern side of the London Basin, and he has found the mineral assemblage to be one of remarkable constancy of character. The number of heavy minerals occurring is not large, but the whole suite is invariably present and the minerals always exhibit the same individual characteristics and occur in the same relative order of abundance. The assemblage of minerals (of specific gravity greater than 2·80) is chiefly characterized by the presence of kyanite, tourmaline, zircon, staurolite, rutile, ilmenite with leucoxene, magnetite, limonite, and glauconite. Others, such as colourless garnet, hæmatite, pyrite, anatase, and very rarely andalusite, occur. With regard to the glauconite, which is always present, no definite idea of its degree of abundance can be arrived at, since the amount of iron present in the mineral appears to vary, and the consequent variability of its specific gravity governs its behaviour in the heavy liquid.

The heavy residues from the quartzite pebbles were precisely similar to those from the Woolwich and Reading Beds. The same minerals occurred, in the same relative order of abundance and exhibiting the same individual features in each case. No mineral occurred, which had not been noted in the Eocene residues, and, of the specially characteristic minerals of the latter, there was no absentee in the residues from the quartzites. In view of this evidence it would seem that these pebbles are not foreign rocks derived from a distance and incorporated in the pebble-beds, but that they are closely related to the Lower Eocene beds.

In pursuance of this idea it becomes necessary to inquire into the evidence for the occurrence, in the Lower London Tertiary beds, of material similar in character to these pebbles, and at once the much debated "greywethers" or "sarsen-stones" are recalled. Prestwich, as long ago as 1854,[1] dealt in a full and admirable manner with the question of the source of the "Druid Sandstones", and the arguments he brought forward are just as cogent to-day as they were when he wrote. He concluded first, from the then available evidence, that the distribution of these "Druid Sandstones" was more in accordance with the range of the Lower London Tertiaries than with that of the Bagshot Sands. This conclusion has been endorsed by later workers. Prestwich then proceeded to consider the three members of the Lower London Tertiaries separately as possible sources of these sandstone blocks. He discarded the Thanet Sands on the ground that although they often present favourable elements and are occasionally semi-indurated, they are rarely consolidated. In the case of the section at the Reculvers, where the Thanet Beds contain a bed of concretionary sandstone, he pointed out that the sandstone has a calcareous cement, contains no pebbles, and frequently exhibits the impressions of shells; whereas the erratic sandstones of Kent, Bucks, and Wiltshire are neither calcareous nor fossiliferous, and are not uncommonly sub-conglomeratic. He pointed out, further, that the Thanet Sands do not range more than 6 to 10 miles westward of London. He next considered his "Basement-bed of the London Clay", with which at that time (1854) were included the present Oldhaven or Blackheath Beds. He alluded to the facts that the "Basement-bed" presents a very small development westward of London, and that although it often contains concretionary blocks they are almost invariably small, calcareo-argillaceous, and fossiliferous. He then stated his belief that the greater portion of the blocks known as Druid Sandstones, greywethers, sarsen-stones, and puddingstones were derived from the middle division of the Lower London Tertiaries. He admitted that it was very rarely that solidified portions of the strata were found in situ, but stated that the same difficulty occurred in as great a degree with the sandstones of the Bagshot Sands. He was able, nevertheless, to put

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[1] Prestwich. "The Woolwich and Reading Series": Quart. Journ. Geol. Soc., vol. x, 1854, pp. 123–30.

forward a certain amount of evidence of the occurrence of sandstone blocks in situ in the Woolwich and Reading Beds, and further supported his view by referring to the definite proof furnished by the cliffs of St. Marguerite, near Dieppe, where a bed of sand underlying the fossiliferous Woolwich fluviatile clays contained in several parts of the section blocks of a white saccharoid concretionary siliceous sandstone, which often contained rolled flint-pebbles and subangular flints.

Mr. Whitaker, in the London memoir,[1] expressed his agreement with the conclusions of Prestwich, but experienced similar difficulty in pointing to definite evidence of sarsen-stones in situ in the Woolwich and Reading Beds. Now, however, the needed evidence is available. Genuine sarsens have been seen in situ in Reading Beds, at Long Valley Wood, near Rickmansworth,[2] and at Nately Scures, Hants.[3] In the London area great difficulty is occasionally caused in sinking through the lower part of the Woolwich and Reading Series by the puddingstones and sarsen-stones, which occur in lenticular masses and offer enormous resistance to the chisels. The sarsen-stone is the less common, but has been met with in the east and north of London.[4] It was encountered in the Tube Railway between King's Cross and the Angel, and also at Gerrard's Cross. When the Rotherhithe Tunnel was made the engineers came upon a very interesting occurrence of sarsen-stone and puddingstone in the Woolwich and Reading Beds. At first a fine, hard sandstone was encountered, and after a considerable length of this had been cut through, the sarsen began to contain small, scattered flint-pebbles. These became larger and more numerous till the rock finally passed into a puddingstone. It did not retain this character further on; patches only were cemented, the rest was loose, thus becoming the normal pebble-bed.[5] It thus appears that the cemented pebble-bed or puddingstone passes laterally into cemented sand or sarsen. Mr. G. Barrow states that, in addition, it may pass either above or below into sarsen, for loose blocks have been found in great numbers containing the junction of the two, the matrix of the puddingstone and the sarsen having exactly the same composition and structure. He states that such blocks are extremely numerous to the west of Great Missenden. Near Cuffley, where the new line of the Great Northern Railway crosses the Cuffley Brook, the puddingstone has been well seen in situ in the Reading Beds.[6] In the Woolwich area local induration of beds by silica is a common phenomenon. It is quite common, for instance, for the bed of

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[1] Whitaker, *Geology of London* (Mem. Geol. Surv.), vol. i, 1889, p. 479.

[2] Hopkinson, *Middlesex and Hertfordshire* (Jub. Vol. Geol. Assoc.), pt. i, 1909, p. 46.

[3] Proc. Geol. Assoc., vol. xxii, pt. iv, 1911, p. 242.

[4] *Records of London Wells* (Mem. Geol. Surv.), 1913, p. 7.

[5] Barrow, Proc. Geol. Assoc., vol. xxx, pt. i, 1919, pp. 5–6.

[6] Proc. Geol. Assoc., vol. xxv, pt. i, 1914, pp. 77–8.

Ostrea bellovacina in the Woolwich Series to be encountered in a silicified condition. This has been well seen in borings at Woolwich Arsenal, and also at Well Hall, near Eltham. The cementation of this bed is, however, frequently ferruginous in character. The same is true of the indurated masses so often seen in the Blackheath Pebble Beds of this district. At the large brick-pit at South Bromley patches of flint-pebbles cemented in a siliceous matrix have been seen in pebble-beds separated from the London Clay above by about 20 feet of sands, clays, and pebble-beds,[1] but it appears to be much more usual to find that where the Blackheath Pebble Beds are locally cemented into conglomerate, the cement is largely ferruginous in character. Such was the case, for instance, at the Kidbrooke Tunnel.[2] On Plumstead Common, near the bandstand, is a large mass of Blackheath Pebble Beds (an outcast mass from some very old gravel-pits, now vanished) firmly cemented into a hard pudding-stone by a cement which is apparently more ferruginous than siliceous.

On the Continent, in Belgium, and North France, sarsen-stones are of common occurrence in the beds equivalent to our Woolwich and Reading Series. Mr. L. D. Stamp, who has recently familiarized himself with the Eocene sequence in these areas, informs the writer that the occurrence of sarsen-stones in the fluviatile facies of the Upper Landenian of Belgium and the Sparnacian of the Paris Basin is a characteristic feature.

At the present time it appears that results afforded by inquiry along three independent lines now point to a common conclusion. In the first place, as the result of the search for evidence concerning the origin of the sarsen-stones, it may now be taken as satisfactorily established that the Woolwich and Reading Beds have afforded one source of supply. Secondly, study of the petrology of the sarsen-stones has revealed a close affinity between them and the material of the Woolwich and Reading Beds. This question has been investigated by Professor P. G. H. Boswell,[3] who found the mineral suite of the sarsen-stones to be precisely similar to that of the Reading Beds, and who concluded that the distribution, mineral constitution, and general characters of the sarsens indicates their probable derivation from the sands of the Reading Beds. Thirdly, as indicated above, the mineral suite of the quartzite-pebbles of the Oldhaven Beds points to a close affinity between them and the sands of the Woolwich and Reading Beds. All that now appears to be required is some definite piece of evidence indicating a direct connexion of the sarsen-stones with the Oldhaven quartzites, and a recent fortunate find of the writer's apparently affords the necessary connecting-link. The photograph shown in the Plate (Fig. 1) is of a rolled quartzite-pebble which the writer obtained in situ in

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[1] Summary of Progress Geol. Surv., 1913, p. 29.

[2] T. V. Holmes, Proc. Geol. Assoc., vol. viii, 1893–4, p. 154.

[3] Boswell, Quart. Journ. Geol. Soc., vol. lxxi, 1915, pp. 573–4.

Blackheath Pebble Beds exposed in a road-cutting on the eastern side of Plumstead Common. In addition to showing all the usual features of these quartzite-pebbles, the present specimen is specially interesting in virtue of the fact that it contains within itself a large number of rolled flint-pebbles. Numbers of the latter were exposed on the exterior of the pebble, and on fracturing it many more were seen. Slices were prepared for microscopic examination, and were cut so as to include some of the flints. Two microphotographs of these sections are shown (Figs. 2 and 3). The amount of cementing material seen in these slices is less than was seen in sections of other quartzite pebbles (as mentioned above, variation in the amount of cement is characteristic of these rocks), and there is a closer approach to a quartz-mosaic structure, but in other respects all the usual features are exhibited. One point, however, is worthy of mention. In addition to the flint-pebbles, rolled quartz-pebbles were also present. These ranged in size up to about ½ in. in diameter. Fortunately some were cut through in the slices, so that it was possible to determine by microscopic examination that they were quartz-pebbles and not altered flint. The point is of interest since the recorded instances of the occurrence of quartz-pebbles in the Reading Beds are few. Mr. H. J. Osborne White has stated that the occurrence of these pebbles at the base of the Reading Beds is by no means rare, but they appear to have been recorded only from Long Valley Wood, near Rickmansworth, Lane End, Nettlebed Hill, and near Chalfont St. Giles.[1]

The above evidence definitely fixes the age of this quartzite-pebble (and presumably the others) as post-Cretaceous and not younger than the Oldhaven (Blackheath) Beds. The pebble presents the typical flattened ovoid shape and is particularly well rolled. As is well known, the rounding of the pebbles in the Blackheath Pebble Beds is of a very thorough character—in the typical exposures a subangular flint is unknown. The character of the beds suggests that their deposition occupied no great length of time—the time required for the rolling of the pebbles was probably great in comparison. That is to say, the rolling of the pebbles probably preceded their deposition as the Blackheath Pebble Beds. A well-marked plane of erosion separates the Pebble Beds from the underlying Woolwich and Reading Beds, and sections showing "scoops", where the Pebble Beds are seen to rest on low members of the Woolwich and Reading Series or sometimes to cut completely through them and rest on the Thanet Sand, are of common occurrence. It would appear that during this pre-Oldhaven erosion of the Woolwich and Reading Beds, large numbers of flints and occasional sarsen-stones were removed from them, subjected to a great amount of rolling, under conditions which did not, as a rule, permit of the decomposition of the pebbles, whereby the rounding of the latter was perfected, and that finally the pebbles

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[1] Proc. Geol. Assoc., vol. xxi, 1909–10, p. 245 (with further references).

were deposited, in no great length of time, to form the Blackheath Pebble Beds.

From this point of view we may regard the occurrence of these rolled quartzite-pebbles in the Blackheath Beds as additional evidence of the pre-Oldhaven erosion of the Woolwich and Reading Beds.

It is somewhat singular that Prestwich, in the classical series of papers on the strata between the London Clay and the Chalk, appears never to have suggested the possibility of these quartzite-pebbles of the pebble beds being rolled fragments of sarsen-stone. He knew of their occurrence in the pebble-beds, for he stated that he had occasionally found them in situ, and suggested that the similar pebbles of the Westleton Beds may have been derived from the Lower London Tertiaries. He pointed out their difference from the quartzites of the Triassic conglomerates, but suggested the possibility of their having been derived from the Palæozoic quartzites of the Ardennes. The point is the more remarkable inasmuch as Prestwich, in amassing strong evidence in favour of the Woolwich and Reading Beds having been one (and possibly the chief) source of supply of the sarsens and puddingstones, was at pains to emphasize the fact that the pebble beds overlying the Woolwich and Reading Series rest upon a strongly eroded surface of the latter beds, and are themselves derived in great part from the destruction of the lower beds.

Summarizing, in conclusion, the main points put forward in the present communication, the writer contends that without attempting to dogmatize upon the question of the scope and applicability of the term "sarsen", but employing it in the general sense now permitted by usage, as free from the limitations some would impose, the following points may now be regarded as established :—

(1) The sarsen-stones and puddingstones considered here are cemented portions of sandy and pebbly Lower Eocene strata.

(2) The Woolwich and Reading Beds have afforded one source of supply of these stones.

(3) The pebbles of quartzite and siliceous flint-conglomerate occurring in the Oldhaven (Blackheath) Beds are rolled fragments of sarsen and puddingstone derived from the Woolwich and Reading Beds.

EXPLANATION OF PLATE I.

Fig. 1.—Rolled quartzite pebble from the Oldhaven (Blackheath) Pebble Beds. Road cutting east of Plumstead Common. Four-sevenths full size. The quartzite contains rolled pebbles and broken fragments of black flint. Note flint pebble $\frac{3}{8}$ in. long showing on surface of quartzite at left-hand end of photograph. The quartzite also contains rolled pebbles of white quartz.

Fig. 2.—Section of pebble shown in Fig. 1, showing flint. Ordinary light. Magnified six diameters.

Fig. 3.—Section of pebble shown in Fig. 1, showing flint; quartz-grains rather closely packed, not much cement. Crossed nicols. Magnified eighteen diameters.

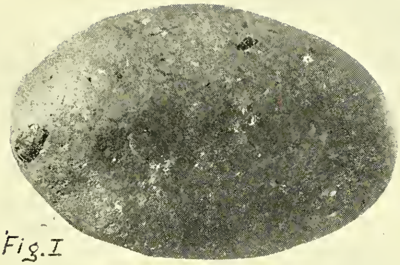

Fig. I

Fig. II

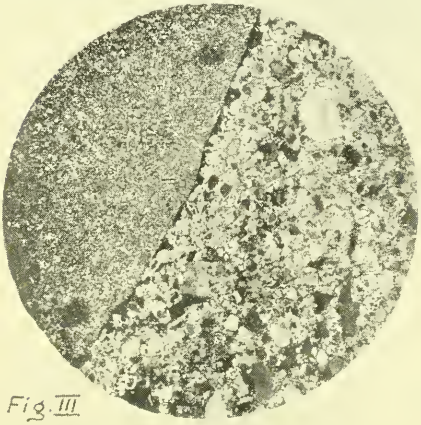

Fig. III

G. S. S. *photo et photomicro.*

Quartzite Pebbles of the Oldhaven Beds.

[To face page 70

The Chines and Cliffs of Bournemouth.

By HENRY BURY, F.G.S.

I. THE CHINES.

THE country round Bournemouth consists of a wedge-shaped plateau, lying between the River Stour and the sea, and ranging roughly from 100 to 200 feet above sea-level. Of the numerous valleys which intersect it, those that join the Stour present as a rule no special features, but most of those running down to the sea are of exceptional character and are known as chines—a term which does not admit of very accurate definition, but is generally applied only to valleys of more than usual steepness.

It is somewhat remarkable that, although the Geological Survey has published two editions of its memoir on Bournemouth,[1] in neither of them is any attempt made to deal with either the form or the origin of these chines. Several other writers, however, have noticed them, and have made suggestions as to their origin; Lyell,[2] for example, thought that they originated as the result of landslips, though he does not attempt any details of the process or explain how the country was drained before they arose. Mr. Starkie Gardner[3] considered them as simply enlargements of the innumerable furrows cut by the rain in the cliff-face, and even speaks of new chines being formed in the course of a few days; while Dr. Ord[4] takes practically the same view, for after describing in detail the formation of these cliff-furrows, he adds: "These illustrate the first step in the formation of our chines." It is clear, then, that while these three authors differ somewhat in detail they are all agreed in regarding these valleys as having started in comparatively recent times in the face of the cliff, and having lengthened themselves by growing rapidly inland. But although a few of the minor indentations of the cliffs may possibly have been formed in this way, yet with regard to all the principal chines—all, at least, that are named as such in the 6 in. map of the Ordnance Survey—there are strong reasons for doubting whether this hypothesis is correct.

In the first place, if the chines are actually growing longer, their rate of growth must be greater than that of the recession of the cliffs; and since the latter is known to be in the neighbourhood of a foot a year, the heads of the chines should exhibit signs of very great activity. Now a rough measure of such activity can be obtained; first, from the angle of slope, which is far less at the heads of the chines than in the cliffs; and secondly, from a study of the vegetation. The face of the cliff is so steep and is

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[1] *The Geology of the Country round Bournemouth*, 1st edition, 1898; 2nd edition, 1917.

[2] *Principles of Geology*, 10th ed., vol. i, 1867, p. 533.

[3] Quart. Journ. Geol. Soc., vol. xxxv, 1879, p. 220.

[4] *The Natural History of Bournemouth and District*, 1914, pp. 61, 321.

changing so rapidly that plants have no chance of establishing themselves on it, and the same is true of the mouths of the chines, where readjustment to the changing coastline is constantly going on; but the heads of all the principal chines are (or were before man interfered) covered with rank vegetation, and afford no evidence at all of rapid erosion.

Secondly, the form of the chines must be taken into consideration. If we examine the valley of the Bourne (not usually accounted a "chine") we find the sides rather steep, but the bottom wide and fairly flat; in fact, in section it has the form of a broad letter U. In Durley Chine, on the other hand, the sides are exceedingly steep and the bottom narrow, so that a section takes the form of a V. Passing next to Branksome Chine (or Branksome Glen [1]) we find both these forms represented, the upper portion of the valley (i.e. that furthest inland) being wholly of the U type, while the lower (from just above All Saints Church down to the sea) has a V-shaped ravine carved in the floor of the U (Fig. 1). Clearly, then, we have two valleys of different ages, a newer and steeper one which alone contains water, and an older one which is more than twice as wide and as long, being traceable inland almost as far as Parkstone Station, where it is truncated by the slope leading down to Poole Harbour; while at the other end, after forming a well-marked terrace on each side of the newer valley, it ends somewhat abruptly about 50 feet above sea-level. It is, in truth, a hanging valley, but its relation to the cliff is obscured partly by alterations due to man, and partly by the fact that it curves towards the east at this point, and was formerly continued for some distance in that direction almost parallel to the present cliff. The latter is exceptionally low opposite Branksome Tower Hotel [2] for this very reason, namely, that it is here a section of the old valley floor (valley gravel, though not shown on the geological map, can be seen capping it), and not, as elsewhere, a section of the plateau (Fig. 2). This double structure can be traced in all the principal chines of Bournemouth Bay, as well as in the "Bunnies" of Christchurch Bay;[3]

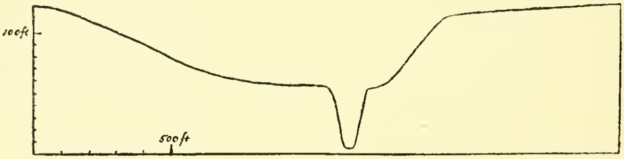

Fig. 1.—Transverse section of Branksome Chine.

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[1] The latter name is used by Mr. Starkie Gardner, the former by the Ordnance Survey, by which what used to be known as "Branksome Chine" is called "Branksome Dene Chine".

[2] See Mem. Geol. Surv., *Bournemouth*, 2nd ed., p. 23, fig. 5.

[3] Quart. Journ. Geol. Soc., vol. xxvi, 1870, p. 532.

but is absent from the so-called "Bottoms" which run down to the Stour and the Avon. In Boscombe Chine, as in Branksome Glen, the older valley is deep and comparatively long; but in the shorter chines (Alum, Durley, etc.) the remnant of the old valley is so shallow and extends so little beyond the head of the newer one, as to be easily overlooked (Fig. 3), especially as its natural form has been much altered by the hand of man. It can, however, still be easily traced by slight changes in the gradients of the roads (Western Road, West Cliff Road, etc.), as well as, here and there, by terrace-like fragments of the old valley floors. In the valley of the Bourne human interference has obliterated almost all traces of this structure, but some (chiefly in the upper parts of the valley) are still visible, while others can be inferred from historical data.

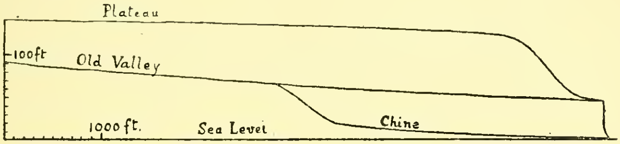

Fig. 2.—Longitudinal section of Branksome Chine.

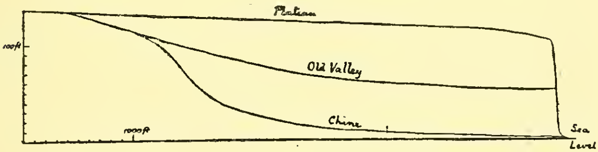

Fig. 3.—Longitudinal section of Alum Chine.

It will be observed that the peculiar structure of the valleys described above is in no way accounted for, or even considered, by the hypotheses hitherto put forward to explain the origin of the chines, and we must therefore look elsewhere for the cause. It will hardly be disputed that the smaller size of the newer valleys (to which alone, as a rule, the name "chine" is applied) is mainly, if not wholly, due to meteorological changes. There may have been in the past a far greater rainfall than now, but having regard to the porous nature of the soil, and the way in which the great width of the old valleys is maintained right up to their points of origin in the plateau, it is probable that they were formed in a period of intense cold, when the ground was rendered impervious by frost. The floors of these valleys are often covered with gravel and cemented sand, and the evidence on the whole seems to point to their having been formed in the time of the Coombe Rock—that being the latest period of intense cold of which we have clear and widespread evidence along our southern coasts.

But we have still to account for the difference in level between the old and the new valleys. If this feature had been common to all the valleys of the district we should have been justified in postulating a change in relative sea-level, and perhaps connecting the old valleys with the well-known raised beaches, rather than with the later period of the Coombe Rock, when the sea had sunk somewhat below its present level. But we have seen that the difference in level is confined to those valleys which run down to the sea, and a little consideration will convince us that, though a change in sea-level is not in itself improbable, the mere encroachment of the sea on the land is quite sufficient to produce the observed phenomena.

There are strong reasons for believing that in former times a river (Solent River) ran across what is now Bournemouth Bay, being cut off from the English Channel by a line of hills connecting the Isles of Wight and Purbeck; and although opinions differ as to the exact time at which its southern boundary was breached by the sea, yet the balance of evidence seems in favour of a fairly late date.[1]

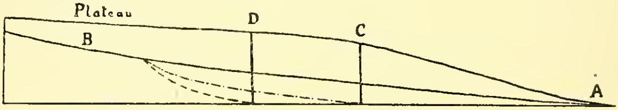

FIG. 4.—Longitudinal section showing the relation of the old and new valleys to the changing shore-line. A, Solent River. B, Floor of old valley. C and D, Successive positions of the cliff, with the floor of the new valley (dotted lines) adjusted to them.

The lateral streams from the Bournemouth district would probably meet this river about one or two miles from the present coast, but the destruction of the river by the sea and the subsequent recession of the coastline have led to a shortening of their valleys and consequent readjustment of the thalweg to new gradients. Owing, however, to the greatly reduced size of the streams, only a short and narrow portion of the old floor was affected, thus giving rise to the chines, as shown diagrammatically in Fig. 4. The same figure also explains how, without any change in sea-level, the remnants of the old valley floor appear at higher and higher levels in the cliffs as the latter recede.

There is, it is true, no direct evidence that the Solent River survived to quite so late a date as is here suggested, but the wide floors of the old valleys must have required time for their formation, and appear to me more consonant with a fixed outfall into a main river than with a shifting one into a constantly encroaching sea—and the conditions are such as to render a stationary coastline highly improbable. Moreover, while it seems certain that chines,

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[1] Mem. Geol. Surv., *Bournemouth*, 2nd ed., 1917, p. 48.

both here and in the Isle of Wight,[1] are due to the advance of the sea, I see no evidence of that advance in earlier structures.

The difference between the hypothesis supported by Lyell and others and that here advanced may be summed up as follows: According to the former the chines originated in quite recent times as miniature torrents in the cliff-face, and have since been growing steadily longer and less steep (longitudinally); while in my view, although the chines themselves (reserving this term for the newer valleys) are recent, yet they are the remnants of an old drainage system which anteceded the cliffs; and since the growth at the head is, if not absent, at any rate less rapid than the advance of the sea, they must each year be growing shorter, and will (unless marine erosion is permanently checked by man) ultimately disappear altogether.

II. The Cliffs.

The suggestion (first advanced, I believe, by Mr. Carus Wilson) that there has been a general increase in the steepness of the Bournemouth cliffs in the last thirty or forty years, has been widely accepted, and coupling this belief with a tradition of a marshy tract of shore, Dr. Ord[2] builds up an elaborate theory of an old sea-cliff left far inland at the time of the raised beaches, and only recently reached again by the sea. But before we accept such a speculative view we must be absolutely sure of the facts on which it rests.

As there is nothing to show that the marshy tract was anything more than an extension of the valley floor of the Bourne,[3] and as it in any case admits of a simple explanation,[4] it need not be further discussed; but the alleged change in the angle of the cliffs merits closer attention.

My own intimate acquaintance with the western part of the bay (from Alum Chine to Poole Harbour) goes back fifty years, and rests further upon many conversations with one who had been familiar with that coast for some ten or fifteen years before; and I am quite confident that, at any rate within the region named and the time specified, the general angle of the cliffs has undergone no change whatever. Moreover, Lyell, who visited this coast in 1830, evidently found erosion going on rapidly, since, as we have seen, he attributes the origin of the chines to falls of the cliffs. On the other hand, the evidence in favour of change having occurred appears to me to amount to nothing more than this, that *at certain points* the cliffs were formerly more easily scaled than now, and for this, I think, local causes can be found without postulating a wide stretch of raised beach, which is entirely unsupported by evidence.

We have seen that the chines are growing shorter, and from the condition of a few of them (notably Little Durley Chine) we may

[1] Quart. Journ. Geol. Soc., vol. xxvi, 1870, p. 541.

[2] *Natural History of Bournemouth*, pp. 234–5.

[3] Lyell, op. cit., vol. ii, p. 531.

[4] Mem. Geol. Surv., *Bournemouth*, 2nd ed., p. 66.

safely infer that some of their lateral branches have already been obliterated. But the normal angle of the head of a chine is less than that of the cliff, and therefore there will come a time when all that is left of the former is an indentation of the line of the cliff, somewhat less steep than the latter; and if, as happens in more than one instance, the chine ran parallel with the cliff, this diminished steepness might extend for a considerable distance. This I believe to be the true explanation of some at least of the observations on which Dr. Ord and others have relied, but it is not improbable that immediately to the east of the pier another cause may also have been at work.

The ordinary gradient of the beach is greater than that of such a valley as the Bourne, and even at low water it is rare for more than 100 yards of shore to be exposed. But it is evident from Lyell's account of the submerged forest that in 1830 a very different gradient obtained opposite the Bourne, for he describes it as situated 200 yards from the mouth of that valley and as lying between the beach and a bar of sand about 200 yards off. Such a diminished gradient is easily accounted for as the result of the resistance of the peat in which the forest grew to the action of the waves and tides; but the effect of it would probably be to form a sort of groin, which might (since the beach materials normally travel from west to east) afford a good deal of protection to the cliffs on the Boscombe side of the Bourne, and give them time to assume a very moderate slope compared with other parts of the coast. For many years, however, the submerged forest has been seldom visible,[1] and there has been no such decreased gradient opposite the Bourne. This has once more exposed the cliffs to the full force of marine erosion, and in this way we may perhaps account not only for the changes in gradient, but also for the alleged special activity of this erosion between Bournemouth and Boscombe.[2]

Quartzose Conglomerate at Caldon Low, Staffordshire.

By F. Barke, F.G.S., Wheelton Hind, M.D., B.S., F.R.C.S., and A. Scott, M.A., D.Sc.

In the Geological Magazine for February, 1919, J. W. Jackson and W. E. Alkins[3] described the occurrence of a quartzose conglomerate at Caldon Low, Staffordshire. In August one of us (F. B.)[4] pointed out some previous references to this outcrop. The curious and ambiguous reply by Messrs. Jackson and Alkins[5]

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[1] The peat does not seem to have been broken up, but to have sunk down, which goes far to support Lyell's contention that in this particular case the submergence of the forest is due more to undermining of the peat than to any general change in sea-level.

[2] *Natural History of Bournemouth*, p. 63.

[3] Geol. Mag., Vol. LVI, 1919, p. 59.

[4] Ibid., p. 384.

[5] Ibid., p. 430.

to this letter necessitates a detailed and accurate description of the history and present condition of the exposure. This reply was particularly ungracious, since one of us in December, 1918, immediately after the reading of Mr. Jackson's first paper at Manchester on the subject, had communicated to him the fact that this quartzose conglomerate had been known to local geologists for many years, and had been shown to the members of the Geologists' Association during the excursion to North Staffordshire in 1890.

To settle finally the position of the quarry which we propose to discuss, and which is the same quarry as that described by Jackson and Alkins, its longitude is 1° 53′ 10″ W. and latitude 53° 2′ 20″ N., and the height is about 900 feet above O.D.

Previous History.—In an address delivered in 1873, Wardle[1] mentions the existence of a sand and clay deposit at Caldon Low, and this pit was first visited by two of us in 1889. It was then in part a sand- and clay-pit of the type which is found in the Weaver Hills, with pockets of sand and clay in the centre and masses of conglomerate at the edge. It was very briefly mentioned in the report[2] of the visit of the Geologists' Association in 1890, but no one could be blamed for not recognizing the spot described. However, this was remedied by J. A. Howe in his paper,[3] "Notes on the Pockets of Sand and Clay in the Limestone of Derbyshire and Staffordshire." In 1905 the North Staffordshire Railway Co. began to extend their quarries northwards, and, clearing away the small pocket of sand and clay, laid bare a basin-shaped mass of quartzose conglomerate in which they drove a small siding in an eastward direction. This fact was noted in the report of the Geological Section of the North Staffordshire Field Club.[4]

Present Condition of Exposure.—At the present time the quartzose material is being rapidly quarried away, and on both north and south faces of the cutting the actual junction of the conglomerate with the undisturbed and well-bedded limestones, which here form a low anticlinal, the northern limb dipping north at an angle of 20°, can be clearly seen. The contact which forms the western boundary of the conglomerate can be traced on both sides of the cutting from the top of the quarry faces to the floor, the angle of inclination being variable, but averaging about 50° to 60°. In the centre the bottom of the deposit is not visible, as it passes under the floor of the cutting. Near the junction the quartzose material shows vertical bedding and is much more conglomeratic than towards the centre.

At the eastern end of the cutting the contact with normal limestone also rises quickly, but not to the top of the face, as a thin bed of conglomerate about 1 foot thick, with a bed of crinoids above it and normal limestone below, is seen to pass eastwards. On tracing

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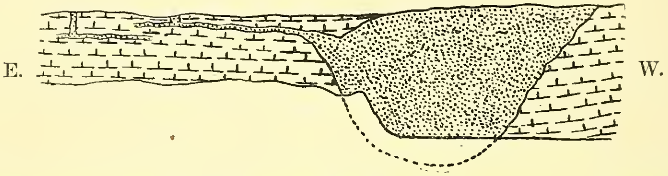
[1] North Staffordshire Field Club: Addresses, Papers, etc., 1875, p. 34.

[2] Proc. Geol. Assoc., vol. xi, 1890, p. 130.

[3] Trans. North Staffordshire Field Club, vol. xxxi, 1897, p. 143.

[4] Ibid., vol. xl, 1906, p. 85; vol. liii, 1919, p. 101.

this bed, which, although fairly level, does not always maintain the same stratigraphical horizon, it suddenly rises to the top of the quarry by a vertical pipe 2 or 3 feet in diameter. A little further east another pipe of conglomerate comes down from the top and connects with another thin bed at a lower level than that a few yards away. As a whole, the field relations suggest that the conglomerate fills a subterranean hole in the limestone, probably formed by solution, the thin beds representing several underground watercourses leading into the main hollow. The question of a contemporary deposit of quartz conglomerate does not, therefore, arise, and there is no connexion with the quartz-pebbles in beds of D_2 age at Castleton.



Diagrammatic section (E.–W.) showing the quartzose conglomerate (dotted) at Caldon Low. The uppermost line represents the top and the lowest line the bottom of present exposure.

The occurrence of fossils in the conglomerate is interesting. The fauna at once strikes one as a D_2 assemblage and quite different from and having nothing in common with the fauna of the Caldon Low Limestones. We consider that the fossils are all derived, because, first, the fauna of the conglomerate is a mixed one; secondly, examination of thin sections shows a shattering of the fossils, many of them being in a fragmentary condition; thirdly, the typical fine-grained limestone of Caldon Low is found in angular blocks in the conglomerate. These blocks are very much larger than any of the other detrital materials, and this, together with their unrolled condition, suggests that they have fallen from the sides or the roof of the subterranean hollow. Mr. Howe[1] mentions the fact that a block of Pendleside shale, containing *Posidoniella minor*, was found by one of us in the clay-pit formerly on this site.

The horizon of the Caldon Low Beds may be definitely assigned to the base of the Viséan. The fauna is a very limited one and exactly similar to the homotaxial equivalents of the Clitheroe and Belgian provinces. *Caninia* should occur near this horizon. Brachiopods are limited to *Productus humerosus*, *Chonetes papilionacea*, C_1 form, and *Orthotetes* aff. *crenistria*, C_1 form. Corals are represented by a very small form of *Syringopora*, gasteropoda by very large species of *Naticopsis*, *Bellerophon cornuarietis*, and other species of this genus. A fragment of a large *Myalina* is the only pelecypod which has been obtained.

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[1] Loc. cit., p. 144.

On comparing the above with the list given by Messrs. Jackson and Alkins, it will be noted that the fauna of the conglomerate is quite a different one, and is indicative of a much higher horizon. Beete Jukes was evidently correct when, in 1839, in a section across North Staffordshire in his paper, "Sketch of the Geology of Derbyshire,"[1] he shows the beds at the base of Caldon Low to be fairly low down in the series.

Petrography of the Conglomerate.—The pebbles in the conglomerate vary greatly in size and in number, and comprise many rock types. The largest are the angular and subangular blocks of grey Caldon Low limestone, while smaller but rounded fragments of the same material are common. In general the material of finer grain is decidedly water-rolled. So far as distribution is concerned, the marginal portions of the conglomerate are much less rich in pebbles than the interior, but even in the latter the proportion of visible detrital material varies from place to place. In addition to the rock containing large limestone fragments, several distinct types of conglomerate can be distinguished; first, a rock containing numerous pebbles, up to an inch or two in diameter, with relatively little matrix; secondly, a similar but more fine-grained rock; and thirdly, a very fine-grained limestone, with abundant minute fragments of quartzose material. The pebbles include fragments of grey Caldon Low limestone, fossiliferous limestone, several types of quartz rocks, cherts, shales, Lydian stone, and some altered igneous material.

Several specimens of the conglomerate and the normal Caldon limestones have been sectioned and examined microscopically. The ordinary Caldon Low limestone shows no trace of quartzose material, and is composed mainly of organic remains, including brachiopod shells, crinoid stems, fragments of corals, tests of foraminifera, etc., in a matrix which is apparently structureless, and was probably a calcareous mud originally. Crystalline calcite, apart from veins and joints, is conspicuously absent. The larger fragments of limestone in the conglomerate are very similar.

The coarse quartzose conglomerate consists of several types of rocks and organic fragments cemented together by relatively large crystals of calcite. The shells and other calcareous materials are obviously fragmental, and the lack of internal structure and optical homogeneity of many fragments suggest that recrystallization has occurred. Often the calcite of the matrix has crystallized round the detrital limestone in such a way as to be optically continuous with it. Pieces of dolomitized material and oolitic grains can also be seen.

Several types of quartz-rock are present. Vein-quartz occurs commonly, each piece being optically homogeneous except for the presence of strain shadows, which are sometimes so prominent and so orientated as to indicate that the material has undergone

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[1] *Analyst*, vol. ix, 1839, p. 2.

considerable pressure. This effect is very similar to the one commonly observed in Bunter pebbles. In one specimen of the conglomerate the detrital material is mainly vein-quartz, and practically every pebble shows decided traces of the effect of pressure. The occurrence of this rock, with such a large proportion of vein-quartz, is interesting, as bands of similar material can be observed in some of the sand- and clay-pits near Friden, Derbyshire.

In many specimens the pieces of vein-quartz, although originally of a rounded form, have invariably a marginal development of secondary quartz in optical continuity with the original grain, and possessing perfect external crystal forms. The latter are so sharply defined as to make it practically certain that the secondary growth has occurred in situ, as even slight rolling would have reduced to some extent the perfection of the faces. The presence of secondary growths on quartz has been noticed by Howe [1] in the material from the Ribden Pit.

A pebble of equigranular quartzite, with relatively large interlocking quartz crystals and little visible cementing material, has a decidedly metamorphic aspect, and is probably derived from pre-Cambrian or early Palæozoic deposits. Several types of sandstone which closely resemble some of the Carboniferous rocks of the Midlands are also present. A fine-grained sandstone, which is made up of subangular grains of quartz with subordinate felspar in a siliceous matrix of quartz and colourless mica, is very like some of the local rocks of Millstone Grit age, which have been used for refractory purposes, while other rocks, which can also be matched among the local deposits of the same age, included a coarse sandstone with rounded quartz crystals and scarce felspar in a cement of secondary quartz, and a fine-grained siliceous conglomerate, consisting of fragments of rounded vein-quartz, quartzite, sandstone, and shale in a matrix of secondary quartz and mica. These rocks resemble closely the so-called "ganisters" of the Stockton Brook district.

Another rock which has angular to subangular quartz grains with little or no felspar, set in a mosaic of interlocking crystals of very fine secondary quartz, closely resembles some of the crowstones of the Pendleside Series which occur in the neighbourhood of Congleton. Other equigranular rocks, consisting almost entirely of quartz, with wavy extinction, and thin interstitial layers of cement, are suggestive of the ganisters of the Lower Coal-measures.

Several fragments referable to chert can also be recognized, and others of very fine grain appear to be indurated quartzose shales. The igneous rocks include tuffs, etc., as well as felsites with a decidedly aphanitic texture.

With regard to the proportions of the various rock-types, the fragments of quartz rock far exceed the others in amount, and of these the sandstones and "crowstones" preponderate over the

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[1] Loc. cit., p. 146.

others, except in the bands which are largely composed of vein-quartz. The metamorphic quartzites are relatively subordinate. Many of the quartzite pebbles appear to be derived from local rocks of Pendleside, Millstone Grit, and, possibly, Lower Coal-measures age, while the limestone fragments, according to the fossil contents, are derived from beds ranging from the Caldon Low limestones to D_2 rocks.

On an average the amount of calcium carbonate in the conglomerate does not exceed 20 per cent, and of this at least half belongs to the crystalline matrix. Hence the amount of primary detrital limestone is less than 10 per cent, compared with 85–95 per cent in the normal Caldon Low limestone. The cherts possibly originated in the deposits of that material in the D_2 and Pendleside Beds of Derbyshire. An almost identical lithological assemblage is found in the Bunter beds which occur at a height of 814 feet above O.D. at High Shutt, about 4 miles to the south-west.

The Weaver Sand-pits.—An examination of the sand- and clay-pit south of Ribden Mine, about 1 mile from Caldon Low, gives much help in elucidating the problem of the Caldon Low conglomerate. This large, open pit, which is about 900 feet above O.D., is worked for sand and clay, the former being predominant. It contains pockets of uncemented pebbles, similar in character to those at Caldon Low, but here and there consolidation has occurred, and we find hard masses of quartzose conglomerate like great sarsens, and very similar lithologically to the infilling at Caldon Low. Nowhere are the limestone sides of the pocket to be seen, but the limestone outcrops all round the deposit. In the pit fairly large pebbles, 2 to 3 inches in diameter, are to be seen, and these are typically pitted like the Bunter pebbles. We have observed similar pebbles at the former clay-pit at Caldon Low and in the Derbyshire sand-pits near Newhaven. Moreover, the lithological assemblage at Ribden is essentially Bunter, and very similar to the deposits of the latter at High Shutt.

The sand deposits at Ribden and elsewhere and the conglomerate at Caldon Low have thus many points in common: (*a*) There is a close lithological similarity between the constituent materials; (*b*) each contain a local concentration of vein-quartz pebbles of intermediate size; (*c*) each contain deposits of fine sand; (*d*) in each case the latter shows well-developed secondary outgrowths on the quartz crystals; (*e*) the relative amounts of such materials as Lydian stone are similar. The chief points of difference are the presence of calcareous cement at Caldon Low as compared with the generally unconsolidated nature of the material at Ribden, and the substitution of the large quartzose pebbles at Ribden by the limestone fragments at Caldon Low. The larger blocks have not been transported any great distance, and it is probable that they represent material which has fallen from the sides and roof of the pits; in the one case the sandstone blocks from now denuded

Bunter beds, and in the other the limestone from the roof of Caldon Low limestone.

The lithological examination of the materials of the Caldon Low conglomerate and the sand- and clay-pits of the Weaver Hills and Derbyshire has shown that they are all essentially the same. The deposits in each case were probably laid down by river action, the consolidated nature of the Caldon Low material being due to the fact that the hollow in this case was a subterranean one, dissolved out of the limestone, which would provide the calcium carbonate which forms the cement. So far as the origin of the pebbles is concerned, these include many types of Carboniferous rocks, and, as a whole, are a typical Bunter assemblage ; hence it seems feasible to infer that they are derived from deposits of the latter age.

Conclusions.—The quartzose conglomerate at Caldon Low is not a penecontemporaneous bed deposited unconformably on the Caldon Low limestone, but is an infilling of a subterranean hollow and several underground watercourses in the limestone.

The pebbles are derived mainly from Bunter deposits, and have reached their present location at some period between Bunter and Glacial times.

The fossils in the conglomerate are all derived and mainly of D_2 age.

REVIEWS.

Fossil Plants: A Text-book for Students of Botany and Geology. By A. C. Seward. Vol. IV: Ginkgoales, Coniferales, Gnetales. pp. xvi + 544. 190 illustrations. Cambridge University Press. £1 1*s*.

THE fourth volume, dealing with the remaining portion of the Gymnosperms, brings to a conclusion this important work, of which the first part appeared in 1898. The main bulk of the plant remains of the past has now been dealt with, but the treatment of fossil Angiosperms has been left for future writers, as the author realizes that a reliable summary of our present knowledge of the geological history of the flowering plants would involve an immense amount of labour, and the co-operation of experts in systematic botany. He considers that he is not adequately equipped for this task, and it would seem probable that it will be long before anyone is found to undertake it, unless one of the American palæobotanists steps into the breach.

The whole work has covered the wide and scattered field of palæobotany in a remarkably thorough way, and almost all the important fossil genera have been mentioned or described, both as regards those based on structural material and those formed for impressions. Brief but excellent summaries of the modern plants to which the fossil types are related have been given, and these have been of considerable utility in giving a conception of the nature of the plants which may be represented as fossils by a group of incomplete fragments; they also assist in the explanation of the system of classification employed and indicate what features are of special importance.

In the volume just published a full account of the fossil Ginkgos is given. This is of especial interest to the geologist on account of the widespread occurrence of this group in Mesozoic times, as well as owing to the solitary survivor found to-day in the Maidenhair-tree. It is characteristic of the caution exhibited throughout the work with regard to the multiplication of species, that the first of the 190 illustrations in this volume depicts the varied forms which the leaves of the modern *Ginkgo biloba* may assume. Some palæobotanists consider that Professor Seward is too conservative with regard to species, but it is certainly preferable in a work of this character to keep genera and species united until good grounds can be produced for their separation. For example, in the case of a fossil which is very common on the Yorkshire coast and which often resembles a group of Pine needles, the genus *Czekanowskia* is defined so as to include forms with entire and bifurcated leaves, on account of their similarity in arrangement on short shoots and also because of the close identity of their epidermal structure. Some palæobotanists would separate the forms with entire undivided leaves into the genus *Solenites*, but though this course has not been followed, the view is mentioned and references are given which will enable the student who is interested to investigate the matter for himself.

Several Palæozoic genera, such as *Psygmophyllum,* which have been assigned by various authors to the Ginkgoales are described, but it is pointed out that the evidence on which this classification is based is wholly inadequate.

A considerable section of the book is devoted to the consideration of fossil coniferous woods, a subject which badly needed summarizing in a broad comprehensive way, and which has also been dealt with by Kraüsel in a current number of *Palæontographica.* The majority of the pre-Tertiary petrified woods are of Coniferous affinities; they are by no means uncommon, but their identification has presented many difficulties in connexion with the characters to be used and in their nomenclature. Several previous authors have dealt with groups of woods of a particular age or from a particular region, but a recent comprehensive summary was lacking. The present descriptions and classification ought to be of great assistance to those who wish to determine fossil woods, without making a special study of the recent and fossil forms and reading through the extensive literature on the subject.

The study of fossil coniferous twigs and of the remains of cones has also been greatly assisted by the succeeding chapters. Some forms, such as those from the American Cretaceous had been thoroughly investigated, but a vast mass of unsystematized information existed in botanical and geological literature about other types. The student is invariably puzzled to find Permian twigs described as *Walchia,* while apparently similar types from the Trias are known as *Voltzia* and from the Jurassic as *Pagiophyllum* or *Elatides.* The summaries of the characters of the twigs and cone structures upon which these generic distinctions are founded, will be a great help to both students and investigators, and should assist in standardizing our nomenclature. The examination and criticism of all the evidence by an author who is an enthusiastic student of the recent Coniferæ means a considerable step forward in our knowledge of fossil plants and of the past history of the cone-bearing trees.

The title of student has just been applied to the author of this monumental work, and it is to students in the widest sense of the word that this textbook will appeal. Parts of it will be of great value to the elementary student who is making a first acquaintance with the principal fossil types, but as a whole the work will be invaluable to all who are engaged in a study of the vegetation of past ages. The very copious references to original papers, to discussions, and to the best figures will be of immense help to all who are interested in this great field of knowledge. The list of works referred to in vols. iii and iv which is printed at the close of vol. iv occupies fifty-one pages, and indicates the extent of the literature which has been used in the compilation of this book. There may be many minor points in which the work is open to criticism from those who belong to different schools of thought. A few palæobotanists may disagree with some of the nomenclature which is used, or others may think that a genus in which they are interested has been too scantily treated. But the fact remains that there are few men who are willing or competent to undertake a task of the magnitude which has now been so ably concluded, and all students of fossil plants owe a considerable debt to the author.

H. H. T.

ON THE FOUR VISIBLE INGREDIENTS IN BANDED BITUMINOUS COAL: STUDIES IN THE COMPOSITION OF COAL NO. 1. By MARIE C. STOPES, D.Sc., Ph.D. Proc. Roy. Soc. B., vol. xc, 1919, pp. 470–87, with two plates and a text-figure.

IN this paper the author proposes an extended scheme of subdivision of the component parts of banded bituminous coal, which comprises terms more precisely defined than those formerly used, viz. : "mineral charcoal," "dull coal," and "bright coal". The new classification is as follows :—

(1) Fusain, "Mineral charcoal" or "Mother of coal".
(2) Durain, "dull coal."
(3) Clarain } "bright coal."
(4) Vitrain }

Of these terms the first has been in use for some time in France, but the last three are new. The ordinary appearance of the first two is well known and needs no comment, but there seems to have been considerable confusion in the past as to what exactly "bright coal" is, some authors using the term in its broad sense and others confining it to vitrain. Vitrain is a very brilliantly reflecting and apparently homogeneous substance, with a conchoidal fracture, and occurs generally as small lenses and thin streaks in the clarain. Though the durain and clarain are predominant in the dull and bright layers respectively, these layers are rarely pure, and the dull layers generally contain thin streaks of clarain and the bright layers enclose streaks of durain. Vitrain, however, is always pure and shows no sign of banding.

These four substances behave differently under both chemical and microscopic examination. If pieces of them be placed in the dark on a photographic plate the most intense image is obtained from vitrain, one less intense from clarain, while that given by durain is fainter still. Alcoholic potash causes vitrain to swell and become soft, so that sections can be cut from it with a razor, but makes the other three substances friable. Treatment with strong nitric acid containing a few drops of hydrochloric acid, followed by neutralization, gives with vitrain a clear liquid of the colour of strong tea with no insoluble residue. Clarain also yields a similarly coloured liquid, but contains some fine-grained insoluble residue.

With durain the insoluble residue is larger and coarser and the solution lighter, while fusain is hardly dissolved at all, and a large fibrous residue is obtained.

In thin sections, also, a graduating change of appearances is noticed ; fusain generally is composed of a mass of black and opaque woody tissue with thickened cell walls and empty cell lumina. Durain consists of a black, opaque, granular groundmass enclosing yellow spore coats. Clarain is clear, coloured red and yellow, and abounds with plant structures of all kinds, while vitrain is also yellow and translucent, but without any trace of organic structure.

The paper is illustrated by two plates, one in colours, showing very clearly the difference in the thin sections of the four subdivisions, and in the solutions obtained from them, and also by a text-figure in which their distribution in typical sections of coal is shown by conventional stippling.

W. H. W.

CRYSTALLIZATION – DIFFERENTIATION IN IGNEOUS MAGMAS. By N. L. BOWEN. *Journal of Geology*, vol. xxvii, 1919, pp. 393–430.

READERS of Anatole France's *La Rotisserie de la Reine Pédauque* will remember that M. d'Astarac, having once conceived the notion that sylphs and salamanders have a present-day existence, found no difficulty in explaining quite ordinary happenings in the light of his extraordinary conception. Similarly, though happily his notion rests on foundations more secure than did M. d'Astarac's, Dr. Bowen has no difficulty in explaining all petrological happenings in the light of his crystallization–differentiation conception. In both cases one can observe the same wholehearted devotion to a charming conception, but also the same neglect of the more obvious deductions.

Dr. Bowen criticizes Daly's views on syntexis and maintains that assimilation plays but a minor part in differentiation, for, even though complete abyssal assimilation be admitted, the problem of the splitting of the resultant syntectic magma is still one of separation of phases. He also combats the limestone-syntectic hypothesis of the origin of the alkaline rocks.

In dealing with liquid immiscibility in differentiation, Dr. Bowen considers that this factor is of no importance whatever. He deduces that a blotchy or patchy separation of phases must follow from liquid immiscibility, and from the general absence of this patchiness in natural igneous rocks he concludes that this factor is not operative. In opposition to this conclusion one must point out that the common occurrence of patchy differentiation in quartz-dolerite sills in Scotland has led to the view that liquid immiscibility may sometimes be a most important factor (Glasgow Memoir, p. 148).

Again, Dr. Bowen considers that abrupt transition would not be expected on the immiscibility theory, since an emulsion would result. Where immiscibility has been claimed in Mull as yielding differentiates *in place* perfect transitions occur (Summary of Progress for 1913, pp. 48, 49, 51). Of course, transition may be expected on any theory of gravitational differentiation.

Using the Duluth lopolith as an example, Dr. Bowen discusses the gabbro-granophyre association and claims that this discontinuous variation can be explained by the mechanical straining off of the mother liquor (granophyre) from the already solidified crystals (gabbro) under the influence of pressure. This mechanism is, of course, well known in Britain, though its advocacy by Mr. George Barrow nearly thirty years ago in relation to certain intrusions in the East Highlands (GEOL. MAG., 1892, p. 64, and Quart. Journ. Geol. Soc., 1893, p. 330).

Dr. Bowen's suggestion (p. 417) that banding of gabbros and peridotites is not a form of flow-structure will scarcely receive credence. Here the likeness of Dr. Bowen to M d'Astarac becomes especially close. He believes that banding is a reaction to mechanical stress on a crystal mesh with still fluid matrix, and that the stress tends to give rise to cavities into which the matrix exudes, while the crystal mesh above and below packs. One can scarcely doubt that such an origin would show itself in an orientation of the early minerals with their axes perpendicular to the exudation bands which they border. One has only to look on a large surface of a banded rock—especially of a porphyritic banded rock—to perceive that the mechanism evoked by Bowen has not operated, but that true flow has occurred. Moreover, Dr. Bowen's explanation, on his own theory, would apply only to an ultrabasic rock banded with more acid rock and not to the very common case in which gabbros, for instance, are banded with scarcer ultrabasic layers.

Dr. Bowen discusses the origin of nodules and schlieren in igneous rocks, and considers them to be due to crystal jams resultant from the packing together of crystals at constricted points and their subsequent removal and partial resorption in the main body of the magma. Such filter presses, required here and elsewhere by Dr. Bowen, have been found to be quite unworkable when copied in industrial processes.

This paper must be welcomed chiefly because it will rouse claimants of liquid immiscibility to renewed exertions. There is little, if any, tendency on this side of the water to rule out either settling of crystals (postulated seventy years ago by Darwin) or mechanical straining (postulated thirty years ago by Barrow) as factors in differentiation, but there is a tendency, perhaps a growing one, amongst field-workers to support the claim that liquid immiscibility is a *vera causa* in addition. Field observations will supply, one believes, the key to differentiation.

H. H. READ.

PALÆOZOIC WORMS AND HYDROIDS IN VICTORIA.

F. CHAPMAN (1919, Proc. Roy. Soc. Victoria, vol. xxxi, pp. 315–24, pls. xiii, xiv) claims to have found the gill-plumes of the Silurian worm *Trachyderma,* well preserved in the Melbournian Mudstones near Keilor, Victoria. This evidence confirms the usual reference of the fossil to the Chætopoda, and suggests that it belongs to the Sabelliformia. Mr. Chapman regards *Eotrophonia setigera* E. O. Ulrich, 1879, as similar gill-plumes. This came from the Lower Cincinnatian beds of Covington, Kentucky, not from Cincinnati itself. Mr. Chapman also describes a new Cornulites (*C. youngi*) from Lower Ordovician slates with *Didymograptus caduceus,* on the Moorabool River north-west of Geelong, and claims it as the oldest recorded. On the evidence of a flattened basal attachment, Mr. Chapman believes that this genus as well as *Pteroconus* Hinde (=*Nereitopsis* Green) is a tubicolar Chætopod.

In another paper (tom. cit., pp. 388–93, pls. xix, xx) Mr. Chapman refers some finely preserved specimens from the Lower Palæozoic Lancefield slates to the Hydroid Order Calyptoblastea, under the names *Archæolafoëa* n.g. and *Archæocryptolaria* n.g. He also refers to the same Order the *Chaunagraptus* and *Mastigograptus* of Ruedemann, and describes a new species of the latter as *M. monegettæ.* (See Plate XV in GEOLOGICAL MAGAZINE, December, 1919.) The discovery is an interesting one, for, with doubtful exceptions in the Pleistocene, the only fossils hitherto assigned to this Order are the Dendrograptidæ. Until representatives have been found in the intermediate strata, sceptics will doubt the lineal descent of modern Sertularians and their allies from these ancient forms, however great the external resemblance may be.

A STUDY OF THE BRACHIOPOD GENUS *PLATYSTROPHIA.* By EULA DAVIS McEWAN. Proc. U.S. National Mus., vol. lvi, 1919, pp. 383–448, pls. 48–52.

THIS is a study of the North American species of the well-known Ordovician and Silurian genus *Platystrophia,* leading to a systematic arrangement based on their supposed evolutionary history. We say " well-known ", but, as Miss (or Mrs.) McEwan points out, the determination of the genotype — *Terebratulites biforatus* Schlotheim — is still uncertain. She therefore selects as a new genotype *Platystrophia laticosta* Meek, 1873. This action is surely ill-advised, even if admissible. Two alternative courses are open to a reviser. First to attempt the fixation of the genotype. Schlotheim's description, unaccompanied as it is by a figure, may be unintelligible to a modern palæontologist, but this may only be because of his larger acquaintance with allied forms and his more minute discrimination. Von Buch, we are told, saw the holotype in the Berlin Museum, and had no difficulty in pointing out the slight differences between it and *Terebratula lynx* Eichwald. If the characters he reported are again rendered inadequate by the advance of knowledge, then surely the obvious course is to re-examine the holotype. Has this been attempted? If the holotype has disappeared, then in any attempt to fix the species regard should be paid to Schlotheim's statement that the unique specimen came "aus dem südlichen Frankreich", though Von Buch thought it more probably came from the North (i.e. the Baltic region). The species has always been regarded as a close ally of *P. lynx*, and it ought to be possible to determine that species with precision. If, however, the attempt to elucidate *P. biforata* be given up, then the alternative course is to select as genotype one of the other species mentioned by King (1850) when he established the genus, namely *Spirifer tcheffkini* De Vern., *Porambonites dentata* and *costata* Pander, and *Spirifer terebratuliformis* M'Coy. None of these is mentioned by Miss McEwan, who prefers to select a species introduced twenty-three years later and found many thousand miles from the type-locality. The fact that Miss McEwan lives in Illinois, or even the fact that American intercourse with Germany has been interrupted for a few years, cannot justify this calm setting aside of all early descriptions and material.

So far as North American species are concerned, Miss McEwan's paper continues the line of research initiated by E. R. Cumings in 1903, when on the basis of characters in the young shell he separated the species into Uniplicate, Biplicate, and Triplicate. In the Uniplicate series the single plication on the sinus and the two on the fold continue through life. The Biplicate series starts with a bifurcation of the plication on the sinus and an intercalated median plication on the fold. According as further bifurcations and intercalations do or do not take place, the series is divided into four sub-groups. In the Triplicate series, to which most North American species belong, the single plication of the sinus persists, but is soon flanked by a plication on each side; the two plications of the fold bifurcate. This series is divided into three sub-groups. In two of them called Low Fold and High Fold, the hinge-line is relatively long and the brephic and early neanic stages are similar; in the former sub-group the low rounded fold persists, and the plications of both fold and sinus remain of nearly the same strength; in the latter sub-group the fold becomes high and compressed in the late neanic stage, and assumes an angular appearance owing to the obsolescence of the lateral plications. The third sub-group does not as yet seem to be very clearly defined, but is constituted for large heavy forms generally similar to the *P. ponderosa* of Foerste, and probably arising at various periods as gerontic forms of Low Fold species.

In the groups as thus defined by brephic and neanic characters Miss McEwan recognizes many cases of parallelism and convergence, and these seem to her to show "that the ancestral species had certain latent possibilities . . . transmitted to the various groups and subgroups, and expressed in a definite order whenever the appropriate environmental stimulation was present". This definite order in the succession of the morphic stages is represented in a table under the heading "Orthogenesis", but why this somewhat metaphysical term should be used is not apparent, for it is not easy to see how the order could have been any other. Another table shows how well the classification agrees with the known stratigraphical distribution, except as regards the *Ponderosa* group.

We hope that Miss McEwan will continue her studies, and that she will have the opportunity of extending them to European material.

F. A. B.

BLOCK MOUNTAINS AND A FOSSIL DENUDATION PLAIN IN NORTHERN NELSON. By C. A. COTTON, D.Sc., Victoria University College, Wellington. Trans. New Zealand Inst., vol. xlviii, 1915, pp. 59–75.

THIS paper was written prior to "Block Mountains in New Zealand" (by the same author), in which the subject of block mountains is treated more fully.

The district examined here is a very small one, the writer confining his attention to the "Aorere–Gouland Depression" and the "Gouland Downs Depression", but the theories advanced serve as a working hypothesis which gives much assistance in the interpretation of this particular district. It would appear that the relief which the deformed undermass presumably had in some earlier period had been almost entirely destroyed prior to the deposition of the covering strata. After the period of deposition of the covering strata, there occurred strong differential movements which sketched out the broad outlines of the land forms of the present day, led to the formation of many consequent rivers, and inaugurated the cycle of erosion in which the majority of the details of the surface were developed. This is quite a departure from the interpretation given by Bell in his Parapara bulletin, in which he supposes that maturely dissected mountains occupied the area in the period immediately preceding that in which the covering strata were laid down, and the period of deposition was one of only partial submergence.

PRELIMINARY REPORT ON THE ECONOMIC GEOLOGY OF HAZELTON DISTRICT, B.C. By J. J. O'NEILL. Department of Mines, Geological Survey of Canada, Memoir 110. 1919.

THIS report, though short, is somewhat diffuse. It deals with the mines of an area of 225 square miles, situated 130 miles north-east of Prince Rupert. The region is described as consisting of folded Upper Jurassic sediments with interbedded tuffs and tuff-agglomerates, invaded by batholiths of granodiorite and "small batholiths" and dykes of "granodiorite-porphyry".

The ore deposits are genetically connected with the igneous rocks and occur in veins which are later than the dykes. The lodestuff consists of brecciated material showing two periods of movement and mineralization. The structure of the ores indicates that the earlier mineralization led to the introduction of large amounts of chalcopyrite, with small quantities of gold and molybdenite. Part of the chalcopyrite has replaced secondary actinolite, giving rise to the name "hornblende ore". The later minerals are zincblende, tetrahedrite, argentiferous galena, chalcopyrite (in small quantities), with banded quartz and some carbonates.

The relation of the veins to the granodiorite appears to have a direct bearing on the mineral paragenesis. Thus, those veins which occur within the boundaries of the larger igneous masses are characterized by the additional presence of magnetite and hæmatite, and those near the contact by pyrrhotite and arsenopyrite. Magnetite is stated to have preceded the pyrrhotite, as it has been partly replaced by it. Tourmaline also occurs, rarely. A point of interest here brought out is the relation of the two groups of ores, indicating a phase-sequence of mineralizations, separated by an interval of time, during the last stages of consolidation of the igneous rock. The report is illustrated by excellent microphotographs of polished specimens of ores.

Aids in Practical Geology. By Professor Grenville A. J. Cole, F.R.S., M.R.I.A. Seventh edition. pp. xvi + 431, with coloured frontispiece, 2 plates, and 136 figures. London: Charles Griffin & Co., Ltd. 1918. Price 10*s.* 6*d.*

THIS book was first published nineteen years ago, and it is sufficient testimony to its usefulness that it has now reached a seventh edition. The author has made few changes in the present issue, which does not differ greatly from the third edition; nevertheless, the work is well up-to-date, and such alterations as seemed desirable have been carried out. It is not intended to take the place of an ordinary textbook of geology, but rather to supply an aid to the student working in the field, helping him to interpret what he observes and to determine the character of the specimens he collects, whether they be minerals, rocks, or fossils. It is impossible for a field-geologist to carry his interest very far and to apply his knowledge very closely without some acquaintance with the common types of fossils and of their chronological and evolutionary significance, and the author has done wisely to include an illustrated account of the more important groups of fossil invertebrates. We venture to hope that in a future edition, which should soon be reached, he may add some description of the commoner vertebrate remains, especially such as are found in this country. The work is very appropriately dedicated to the memory of the late Professor Judd.

F. H. A. M.

THE DISTRIBUTION OF ORES OF TUNGSTEN AND TIN IN BURMA. By J. COGGIN BROWN and A. M. HERON. Rec. Geol. Surv. India, vol. l, pt. ii, pp. 101–21, with two plates (maps). 1919.

IN this paper we have at last definite detailed information as to the geological occurrence and relationships of the tungsten and tin lodes of Burma and the neighbouring districts. They extend over an area 720 miles in length, from Byingyi in the Yamethin district, Southern Shan States, to Maliwun in Mergui, in the extreme south. The lodes are closely associated with a very acid granite intruded into the ancient Mergui sediments. Some of the lodes are typical pegmatites and greisens, while others are quartz veins in the narrower sense of the term, but all appear to be of similar magmatic origin. This is supported by the occurrence in places of tourmaline, topaz, and fluorite. The characteristic minerals are arsenopyrite, chalcopyrite, pyrite, molybdenite, native bismuth, and other bismuth ores. At the present time a large proportion of the output of both wolfram and cassiterite concentrates comes from various detrital deposits. Wolfram is rare in true alluvium, but cassiterite is common in places.

Full descriptions are given of the lodes in all the mines, most of which have been inspected by the authors. Hermyingyi is probably at the present time the largest wolfram mine in the world, having produced in 1917 no less than 1,051 tons of concentrates, out of a total of 3,654 tons for the whole district.

REPORT ON A COLLECTION OF CAINOZOIC FOSSILS FROM THE OIL-FIELDS OF PAPUA. By F. CHAPMAN. WITH GEOLOGICAL INTRODUCTION by ARTHUR WADE. Bulletin of the Territory of Papua, No. 5. 18 pp. Melbourne, 1918.

THE oil-bearing strata of Papua skirt the coast on the south-west from Yule Island to the Parari delta. They range, as appears from Mr. Chapman's determinations, from Recent to the base of the Miocene, and below them are some grits, conglomerates, and sandstones, apparently without fossils but with traces of limestone and coal. Mr. Chapman's report is for the present only a list, but as Dr. Wade points out in a most interesting introduction, it is of much importance in working out the classification and tectonics of the strata and in elucidating such wider questions as the relation of Papua to the adjacent land areas.

REPORTS AND PROCEEDINGS.

Geological Society of London.

December 3, 1919.—Mr. G. W. Lamplugh, F.R.S., President; and, afterwards, Mr. R. D. Oldham, F.R.S., Vice-President, in the chair.

Mr. S. Hazzledine Warren, F.G.S., exhibited and commented on a collection of Neolithic implements from Graig-lwyd, near Penmaenmawr (North Wales).

Professor W. W. Watts, Sc.D., F.R.S., exhibited and described a new geological map of Western Australia, prepared by the Geological Survey of Western Australia, under the direction of Dr. A. Gibb Maitland, F.G.S.

Mr. C. N. Harris, Chairman of the Western Australian Committee of the Institution of Mining and Metallurgy and of the Committee of Repatriation, exhibited a collection of minerals from Western Australia which he had presented to the Imperial College of Science and Technology, and commented chiefly on those of economic interest.

The President (Mr. G. W. Lamplugh) summarized briefly the phenomena presented by the dry-lake areas of Western Australia, illustrating his remarks with lantern-slides lent by the Royal Geographical Society. He also exhibited specimens from Permo-Carboniferous glacial deposits of the Irwin River district (Western Australia).

CORRESPONDENCE.

THE SGURR OF EIGG.

Sir,—Mr. Cunningham-Craig is good enough to read me a lecture upon the importance of field-work and the danger of being misled by theories. Had he read my paper before attacking it, he would have seen that the theory which I took with me to Eigg was the same which he is now defending, and it was the field evidence that forced me to a different conclusion.

He would have learnt, too, that the presence of granite fragments in the agglomerate of Bidein Boidheach is no new discovery, but is recorded both in my paper of 1906 and in the memoir on the "Small Isles". From the same and other sources he might have learnt further that this is not an isolated occurrence. Fragments of both gabbro and granite of Tertiary type are found in numerous volcanic agglomerates in Skye, Rum, Mull, and Arran. These agglomerates belong to a very early part of the volcanic succession, and are themselves invaded by the gabbro and granite of the mountains. The existence of this *earlier* plutonic series—nowhere exposed in place, unless it be in Central Mull—is familiar to every student of our Tertiary igneous rocks. Whatever be its significance, it disposes effectually of Mr. Craig's argument.

If, without discourtesy, I may play the mentor in my turn, I would hint in conclusion that a little knowledge, when joined to a large measure of assurance, is a dangerous thing.

ALFRED HARKER.

ST. JOHN'S COLLEGE, CAMBRIDGE.
January 12, 1920.

HÆMATITE IN SOUTH WALES.

SIR,—Allow me to correct a misstatement, serious from the economic standpoint, which is contained in the review of "The Hæmatites of the Forest of Dean and South Wales" (Memoirs of the Geological Survey: Special Reports on the Mineral Resources of Great Britain, vol. x) published in the January number of your journal.

The reviewer states that "the author sees no hope for the resuscitation of the mines under present conditions". On the contrary, the memoir under review describes the hæmatite-field of South Wales as a promising area for development. Thus: "In the hæmatite-field of South Wales . . . recent years have witnessed a successful revival of iron-mining, and the ore-fields give considerable promise for future development" (p. 2); and again: "In view of the high grade of the ore, the comparatively large tracts of undeveloped ground, and the successful mining at Llanharry in recent years, it appears not improbable that the district will produce hæmatite on a larger scale in the future than it has done in the past" (p. 65).

As a matter of interest, I may add that new explorations for hæmatite in the Llanharry district, undoubtedly stimulated by the official geological investigation of the area, have already commenced.

Yours faithfully,
T. FRANKLIN SIBLY.

ARMSTRONG COLLEGE, NEWCASTLE-UPON-TYNE.
January 14, 1920.

OBITUARY.

Henry Charles Beasley.

THE late Henry C. Beasley, who died at Liverpool on December 14, 1919, at the ripe age of 83, was best known to geologists for his work in connexion with the Triassic footprints, especially those found in the Keuper beds at Storeton, Cheshire, and other quarries in the Liverpool district. He published a number of papers in the Proceedings of the Liverpool Geological Society recording his observations, and as Secretary of the British Association Committee for the Investigation of the Fauna and Flora of the Trias of the British Isles, he wrote a series of reports on the footprints for which he proposed a provisional scheme of classification. In 1906 he was awarded the proceeds of the Barlow-Jameson Fund by the Geological Society of London for his geological work in this connexion. He was Secretary of the Liverpool Geological Society from 1890 to 1900, and President for the sessions 1887–9, 1904–6, and again 1908–9, and served as President of the Liverpool Biological Society for 1901–2. His fine collection of footprints was recently purchased by Councillor C. Sydney Jones, M.A., for the Free Public Museum of Liverpool. Mr. Beasley was a most indefatigable and persistent worker at his favourite geological subjects, such work being his relaxation from an active commercial career. His unselfish character and his readiness at all times to assist any fellow-worker endeared him to all who knew him.

W. H.

Francisco Josué Pascasio Moreno.

BORN MAY, 1852. DIED DECEMBER, 1919.

WE regret to announce the death of our friend Dr. Francisco P. Moreno, founder and for many years director of the La Plata Museum. Born in Buenos Aires 67 years ago, he was half English, his mother having been the daughter of an English botanist. He was a collector of natural history specimens from his earliest youth, and he soon began an important series of explorations of Patagonia and the region of the Andes, which lasted from 1873 until 1884. His first scientific paper was a description of some prehistoric cemeteries in Patagonia, published in the *Revue d'Anthropologie* in 1874. Three years later he gave his collection to the Argentine Government, who used it for the foundation of the Anthropological and Archæological Museum of Buenos Aires. In 1880 Buenos Aires became the federal capital, and in 1882 the city of La Plata was established to replace it as capital of the province. In 1884 the provincial governor suggested to Dr. Moreno that he should organize a great new museum in La Plata, taking his anthropological collection as a basis. The special desire of his life was thus fulfilled, and he began to work at once, planning the building and arranging for the acquisition of more collections to illustrate the natural history and antiquities of the Argentine Republic. The excavation of the new docks in the Pampa formation near La Plata especially afforded an opportunity for obtaining a fine series of skeletons of the Pleistocene Mammalia. By 1889 the Museum was nearly complete, and in the following year Dr. Moreno began to issue its well-known series of valuable publications. In 1893, and again in 1894, Mr. Richard Lydekker visited the Museum officially to prepare an account of the fossil Mammalia from the Pampa and some earlier formations, which appeared in the *Anales del Museo de la Plata, Paleont. Argentina*, vols. ii and iii. In 1896 I spent a brief vacation there, and wrote a description of some remarkable Cretaceous crocodiles then recently received from Neuquen, which occupied another part of the *Anales*. In 1899 Dr. Moreno came to London as Argentine High Commissioner in connection with the Argentine–Chilian boundary dispute, which had been referred for arbitration to the British Crown. He then brought with him many fossils for comparison with the collection in the British Museum, and the piece of skin of an extinct ground-sloth from a cavern in Patagonia, with a skull and other remains of the horned tortoise *Miolania* from Chubut, will be especially remembered. Dr. Moreno contributed a "Note on the discovery of *Miolania* and of *Glossotherium* (*Neomylodon*) in Patagonia" to the GEOLOGICAL MAGAZINE, September, 1899. Returning to La Plata he continued to direct the Museum for a few years longer, until he retired to Buenos Aires and lived a quiet life, utilizing his ripe experience in furthering schemes for the improvement of education.

Dr. Moreno's writings on the geography, anthropology, and geology of his native land are important and varied, but they give little idea of the extent of his labours for the promotion of science in Argentina. He was the unselfish friend and helper of all whom he induced to contribute to the publications of the La Plata Museum, and of Argentine naturalists in general. He was ever ready to devote his private means to the advancement of research, and the great collection and library at La Plata bear witness to his generosity as well as to his genius. He was honoured in this country by election as Foreign Correspondent of the Geological Society and as Corresponding Member of the Zoological Society of London. He was also an Honorary Corresponding Member of the Royal Geographical Society, and received the Founder's Medal in 1907.

A. SMITH WOODWARD.

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All Communications for the EDITOR should be addressed to
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All letters for Dr. H. WOODWARD, F.R.S., may be sent to
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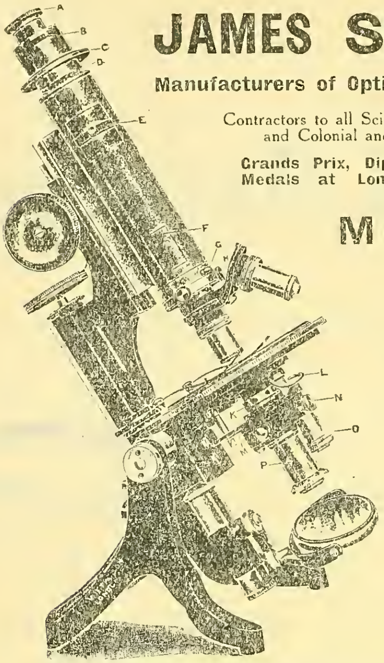
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THE

GEOLOGICAL MAGAZINE

VOLUME LVII.

No. III.—MARCH, 1920.

EDITORIAL NOTES.

THE Annual Report of the Council of the Geological Society of London for 1919, presented at the Anniversary Meeting on February 20, 1920, does not contain any very striking features. It is pleasing to observe that there has been a large increase in the number of new Fellows elected, 81 as against 32 in 1918, and this in spite of the increase of the annual contribution from two to three guineas for Fellows elected after November 1, 1919. During the year it was decided to admit women to the Society, but so far only fourteen have availed themselves of the privilege. The list of medals and awards has already appeared in the Magazine. The publication of the Quarterly Journal has made up some of the leeway, and is now only one year behind date, but the position of the annual index of geological literature seems hopeless, the last issue being that for the year 1912. The continuation of this most useful work seems to be largely a matter of funds, and it is satisfactory to note that the Royal Society has made a grant of £100 towards the publication of the volume for 1913, which it is hoped will soon appear, although its progress has naturally been delayed by the resignation of the Librarian, Mr. C. P. Chatwin. The vacancy thus created has been filled up by the appointment of Captain A. Greig, formerly Assistant Librarian. It is disquieting to find that the estimates anticipate a deficiency of £300 on the working of the Society for the coming year, and geologists who have not yet done so should apply for admission as Fellows, and thus help this, the leading geological society of the world, to maintain unimpaired its great work in the interests of the science.

* * * * *

AT the annual meeting of the Geological Society of America, held at Boston, officers for the year were elected as follows: President, I. C. White, Morgantown, W. Va.; First Vice-President, G. P. Merrill, Washington, D.C.; Second Vice-President, W. G. Miller, Toronto; Third Vice-President, F. B. Loomis, Amherst, Mass. Many papers were read, and a discussion on the teaching of geology attracted much attention. It is an interesting fact that during the meeting two new societies were formed, with the full approval and support of the parent organization. The Mineralogical Society, formed at Cambridge, Mass., elected as its first President E. H. Kraus, of Ann Arbor, and as Secretary H. P Whitlock, of the American

Museum of Natural History, New York. The other new Society, the Association of Applied Geologists, should do much to fill up the gap that now exists between pure geology and the branches of engineering and other sciences and arts bearing upon the exploitation of our mineral resources. We wish both these new societies a long and prosperous career.

* * * * *

Many old Cambridge geologists both at home and abroad will be glad to hear that the Sedgwick Club has entered on a career of renewed activity after the inevitable period of eclipse, due to the War. In the autumn of 1914 the few remaining ordinary members held a meeting at which they appointed a committee, mostly composed of members of the teaching staff, under the chairmanship of the Woodwardian Professor, to hold office till the end of the War, with powers to elect ordinary members. Last May term this committee exercised its powers by nominating sufficient new members to form a quorum, and then extinguished itself. After this matters proceeded in the ordinary way, and the Club is now as flourishing as ever, or even more so, as shown by the following communiqué received from an official source: "The Sedgwick Club has formed a committee for directing and carrying out a detailed study of the Pleistocene and Holocene deposits of the Cambridge district with special reference to questions connected with Ancient Man in Britain. Some years ago a similar committee of the Club studied the distribution of the glacial boulders in the district. The enthusiasm with which that work was carried out, and the interesting results obtained, recorded in a paper by Messrs. Rastall and Romanes (Quart. Journ. Geol. Soc., vol. lxv, 1909, pp. 246–65) augur well for the success of the present undertaking."

* * * * *

With the opening of Parliament the question of the nationalization of mines has again reached an acute stage, and appears likely to be in the forefront of politics for some time to come. In the debate on the Address the Prime Minister spoke words of solid wisdom, and foreshadowed most determined opposition on the part of the Government to the projects for bureaucratic control of our greatest industry. We have already drawn attention in these columns to the fallacies of the prevailing Fabian arguments in support of nationalization of coal-mines. It is currently reported that labour witnesses before the Board of Trade Committee on non-ferrous mining have spoken in favour of nationalization as a remedy for the troubles of their own particular branch. Everything that has been urged against it in the case of coal-mines applies with even greater force to metalliferous mines, and there is here an added argument of the greatest cogency. It is well-known to every one at all conversant with the subject that metalliferous mining, especially non-ferrous, offers much greater uncertainties than coal-mining, and, indeed, is almost always inevitably in the nature of a gamble. This is simply a matter of geology, and it is unnecessary to labour the point. Now it is manifestly impossible for the State to enter upon such a hazardous type of speculation with the public funds as capital; even the most academic economist and the most theoretical socialist must recognize this fact, and the inevitable result of the interference of the State and control by a Government department would be the total stoppage of enterprise and development in this direction and a complete cessation of any production of non-ferrous metals in this country. Such a state of affairs is unthinkable.

* * * * *

The Board of Trade Committee on non-ferrous metalliferous mines has now completed the taking of evidence, and a report is being prepared which it is hoped will be ready for presentation in the course of a few weeks. At the later sittings of the Committee some interesting evidence was given concerning lead, zinc, and barytes. With regard to the last-named product Col. J. V. Ramsden, of the Shropshire Mines, Ltd., pointed out the need for improved methods of preparation, and also for protection against the dumping of cheap foreign material, if the barytes industry in this country is to be preserved. Mr. J. Mitchell, of Wanlockhead, described the scheme for a very long deep-level gravity tunnel for the drainage of the Wanlockhead–Leadhills district. Much evidence was given concerning the present position of the lead-zinc mining industry in the North of England. It was stated that the Ashover Mines in Derbyshire are now worked almost exclusively for fluor-spar, for which there is a good demand as a flux in metallurgical work. It appears that in many localities the visible supplies of ore are now approaching exhaustion, and Professor Louis considered that the allocation of national funds to investigation of the Melmerby Scar Limestone would be justified, as in his opinion this offers the most promising prospects. In this connexion it may perhaps be allowable to point out that purely geological considerations are of great importance. If the ore came from below there should be a tendency for it to accumulate under such an impervious rock as the Whin Sill. Now it is well known that the sill is transgressive, occurring in different places at very various stratigraphical horizons. Hence the most likely place for ore would seem to be in places where the Whin Sill rests on a well-marked bed of limestone, if such can be found. This evidently needs a close and detailed study of local stratigraphy.

ORIGINAL ARTICLES.

On an Inverted Mass of Upper Cretaceous Strata near Leighton Buzzard, Bedfordshire; and on an Overlap of the Upper Gault in that Neighbourhood.

By F. L. Kitchin, M.A., Ph.D., and J. Pringle, F.G.S.

(*Concluded from p. 62.*)

C. Identification of the Strata between the "Silver-sands" and the Inverted Mass in Mr. Harris's Pit.

An examination of the sections at and near Shenley Hill, described above, thus provides the means for a complete interpretation of the puzzling stratigraphical relationships seen in Harris's Pit. The inverted Upper Gault and basal Cenomanian limestone masses have already been identified zonally: the sand-beds distinguished as G and F by Mr. Lamplugh and those parts of his bed D which are not of Cenomanian age remain to be correlated.

The well-bedded, impure, fine sand (G), overlying the "silver-sands", may be recognized as a thin and probably denuded representative of the 6 ft. bed of streaked and carbonaceous sand underlying the *tardefurcata* bed at Miletree Farm (No. 8). The overlying stratum F, a coarser and less well-bedded greenish clayey sand, is here and there rather abruptly separated from bed G, but in other places forms an upward continuation of it. The two may be considered to form part of one deposit. The coarser sand of F occurs as small shallow banks, which are discontinuous in places; when it is absent the next higher bed, forming part of bed D of Mr. Lamplugh (the part designated D_1 in Fig. 2), is then in contact with bed G, which in one place where such a relationship was seen was reduced to 4 inches in thickness.

The sandy beds G and F, of pre-*tardefurcata* age, form the highest member of the Lower Greensand present in this section. They are overlain immediately by the unconformable basal bed of the Upper Gault, with which we have become familiar in neighbouring sections. For convenience we refer to this bed at Harris's Pit as D_1. We have seen that its development, wherever it is normally overlain by the Upper Gault Clay, is that of a continuous basal bed of mixed composition, variable in thickness, and with uneven lower surface. At Harris's Pit it shows less continuity and greater irregularity in its mode of occurrence. The clay which normally overlies it, with the exception perhaps of a few little isolated traces, had been locally removed by denudation before the overturned mass of strata became deposited in this place. The remnants of the basal bed itself, which formed the floor upon which the inverted strata came to rest, may owe some of their present irregularities to the same denudation; but the confused aspect of the bed is doubtless to be ascribed in considerable measure to the stresses and disturbances set up by the weight of the overlying transported mass.

An isolated lenticular portion of this crushed floor, distinguished as D_1 in our illustration, shows only one aspect of the manner in which the bed occurs. The stratum is sometimes continuous for a distance of several yards, occupying most of the space between the "silver-sands" and the inverted Gault above. It then shows the closest resemblance to its normal development, as seen, for instance, at Garside's Pit or at Miletree Farm. Frequently, however, softer portions of the bed dwindle laterally into streaks, and the relations of the deposit to the underlying sand, F, show here and there considerable confusion. It is possible that at the time of the transgression the sandy floor may have become locally churned up and its materials redeposited in close association with the other constituents of bed D_1; but the later addition of the great weight of the superincumbent transported mass of strata, even leaving out of account the added pressure of glacial ice, seems to us to explain sufficiently most of the irregularities in these relatively soft strata. Some of the surfaces now marked by the presence of secondary limonite-segregations, as in the upper part of bed F, doubtless originated by minor disruptions caused at the same time.

Little need be added regarding the lithological characters of bed D_1. These are variable, just as at the other localities where this basement-bed occurs. In places the coarser constituents, that is to say the rounded pebbles and grit-grains, the angular or subangular platy fragments of ironstone, and the polished hollow pebbles of ironstone, are segregated so that such portions of the rock almost form a breccia. Other parts show a finer and more even composition, so that the yellowish and brown sandy or gritty clay-matrix then contains few of the ironstone-fragments. Small pockets of greenish and brownish clay also occur. We have already noted the presence in one place of a flat claystone nodule similar to those forming a layer in the passage-bed (of *tardefurcata* horizon) north of Miletree Farm. A few small white calcareous nodules have also been seen, just as in this basal Upper Gault at other localities. In one part of the topmost layer, where the limonite-band, C, dipping down slightly for a short distance, happened to occupy a surface of weakness just below the top of the bed instead of above it, we noticed that the limy nodules were flattened. The matrix in this patch, immediately in contact with the overturned Gault, was horizontally laminar and fissile, owing to a deformation resulting from pressure.

We can throw little light on the palæontological characters of this Upper Gault basement-bed. It is relatively unfossiliferous, and we have done no more than prove that brachiopods occur in it; *Kingena lima* (Defr.) is the only species we have identified. There can be little doubt that a certain number of the brachiopods described by the late Mr. J. F. Walker, from bed D, came from this

Upper Gault deposit. Mr. Walker broke up and examined a large amount of material without discriminating between the blocks of Cenomanian limestone and those from the bed of earlier date. We consider that some specimens of ammonites in that part of the Walker Collection now preserved at Cambridge, kindly submitted to us by Mr. H. Woods for examination, belong without doubt to this earlier bed. They include *Leymeriella regularis* and a finely ribbed species of the same genus, derived from the *tardefurcata* bed, which, as we have shown, was undergoing denudation in the immediate neighbourhood at the time of the Upper Gault transgression. Another ammonite is a rolled fragment of a finely ribbed Perisphinctid, probably of Upper Kimmeridgian origin, of similar aspect to some of those found in the Lower Greensand of Potton; it may have been rederived from that or some similar deposit. We suspect that most of the fossils of Lower Cretaceous character recorded by Mr. Walker from bed D came, in reality, from this basal Upper Gault, in which they occurred as derivatives, and not from the Cenomanian limestone-lenticles. Further collecting on an extensive scale would be necessary in order to allocate to their right beds the species of different ages which were thought by Messrs. Lamplugh & Walker to illustrate a true commingling of life-forms.

The inverted lenticles of Cenomanian limestone lie side by side with the masses and patches of the basal bed of the Upper Gault. The lenticles have been forced down into the relatively soft material of the floor upon which the inverted mass rests. The constituent parts of the two beds, so interlocked and closely associated at the same level, illustrate an uncommon stratigraphical relationship of much interest. Some outer portions of the limestone-lenticles are occasionally seen to have become partly decomposed, and may then closely resemble the finer material of the older bed. The illusion is heightened by the pebbles in the limestone and by the ferruginous staining of both matrices; but the limestone-lenticles in all cases betray their true character by their included fossils.

A few words may be added here on the subject of the limonite-segregations, bands C and E, parts of which lie within the beds of Lower Greensand and Upper Gault just discussed. Referring to these ironstone-sheets, Mr. Lamplugh stated: "There is clear proof that they were in existence as rocky bands before the material now overlying them was deposited."[1] In support of this he called in evidence the fragments of ironstone incorporated in the breccia of bed D and the "polished and worn" surface of the "iron-pan floor" underlying the breccia. Reference was also made to some large blocks on the tip-heap of Harris's Pit, encrusted on their worn surfaces by adherent oysters and *Serpulae*. It was inferred that

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[1] G. W. Lamplugh & J. F. Walker, "On a Fossiliferous Band at the top of the Lower Greensand near Leighton Buzzard (Bedfordshire)": Quart. Journ. Geol. Soc., vol. lix, 1903, p. 240.

these blocks belonged to the ironstone-bed E, which either formed part of the actual "floor" from which the fragments of ironstone in the overlying breccia had been derived, or represented the kind of local contemporaneous deposit in which they had their origin. We may remark that bed E, whenever seen by us, was of such a character as to be incapable of furnishing fragments for the spoil-heap similar to the large blocks described.

Mr. Lamplugh's later observations, recorded in his paper of 1908,[1] seem to give a clue to the origin of the encrusted blocks. In this later communication there is the description of a similarly encrusted sea-worn crag of "ironstone", a few feet across, within the glauconitic greensand then seen overlying the brachiopod-bed. This is clearly an indurated portion of the inconstant Upper Greensand bed. An examination of specimens of this rock obtained by Mr. Lamplugh shows that it differs essentially from the tabular limonitic bands, C and E. In some of the specimens there is shown a ferruginous and siliceous induration, probably of secondary origin, additional to the firm calcareous cementation seen in other parts of the rock; but even these more iron-stained portions do not in reality resemble the limonite-bands.

We thus recognize three distinct categories among the rock-bodies discussed by Mr. Lamplugh under the heading "The Iron-grit Bands".[2] Enumerating these in the chronological order of their formation we have, firstly, the flat fragments of ironstone (excluding the hæmatitic pebbles) incorporated as an original constituent in the Upper Gault bed, D_1; secondly, the indurated masses with worn and encrusted surfaces forming part of the bed of Upper Greensand; and thirdly, the thin undulating and branching sheets which have resulted from mineral segregation since Glacial time. The disposition of these connected sheets, occupying surfaces which mark two unconformable junctions and enclosing portions of beds belonging to three widely different geological dates (one of the beds being in inverted position), proves conclusively that the bands C and E are not an original part of the series. The smooth surfaces of the sheets are not incompatible with the later introduction of the limonite.

D. RELATIONS OF GAULT AND CENOMANIAN AT THE MAIN OUTCROP.

The evidence so far obtained showed that a basal Cenomanian bed of special type formerly existed at the top of the outlier at Shenley Hill, and that the remnants of it seen there in inverted position owed their preservation to the fact that they had become sealed up under a protective mass of Upper Gault clay. It became desirable to ascertain if, anywhere towards the south-east and south, a similar bed at the base of the Chalk escarpment replaces the

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[1] "Excursion to Leighton Buzzard": Proc. Geol. Assoc., vol. xx, pt. vi, 1908, p. 475.

[2] G. W. Lamplugh & J. F. Walker, op. cit., 1903, p. 240.

Cambridge Greensand of the country towards the north-east. No information on this point could be obtained from published writings, and an examination of the ground soon showed that the base of the Chalk was not to be seen in any natural exposure. The lower slopes of the escarpment are covered with a deposit of chalky downwash of variable thickness, and the line of outcrop of the basal bed is either concealed beneath this or is situated in the flatter ground under a cover of Boulder-clay.

The outcrop of the Cambridge Greensand, at the base of the Chalk Marl, is known to extend towards the south-west as far as the neighbourhood of Sharpenhoe, east of Harlington. Here the bed is thinning, and is developed as a bluish-grey sandy clay, about a foot in thickness, with green grains and many nodules. We began our investigations just south of this point, and probed the ground by boring or digging at several localities between here and Wendover. The result was to show that the evidence for a break in the sequence at the base of the Chalk, with signs of erosion, diminishes in a south-westerly direction.

At a spot one mile south-east of Harlington Church the basement-bed of the Chalk, as shown by fragments brought up by a hand-boring tool, was reached at a depth of 10 feet below the surface. It is overlain by 3 feet of cream and pale buff-coloured Chalk Marl, gritty and slightly glauconitic in the lowest foot. The basement-bed is here reduced to a layer which we estimate to be 2 to 3 inches thick. It consists of small well-rounded quartz-grains, black crumbs and polished grains (? phosphate), set in a fine creamy calcareous paste containing pebbles (up to $\frac{1}{2}$ in. in diameter) of rolled quartz-grit, fine quartzose sandstone, and subangular white chert, as well as black phosphatized fragments. This bed is underlain by pale Upper Gault Clay, assuming a darker bluish tint at a lower level.

At Kateshill, 3 miles north-west of Dunstable, a poor exposure in the road-cutting on Watling Street enabled us to ascertain that the basement-bed of the *varians* Chalk is an indurated grey calcareous sandstone with numerous small cream and grey-coloured phosphatic nodules, up to $\frac{1}{2}$ in. in diameter. This bed is underlain by the pale calcareous clay of the Upper Gault, with darker bluish clay at a lower level, as at Harlington.

At Totternhoe and Eaton Bray the outcrop of the base of the Chalk is masked by a thick deposit of chalky downwash. It was evidently due to an error that an outcrop of Upper Greensand at the village of Eaton Bray was represented on the Geological Survey map. The most careful inquiry failed to reveal any trace of it. A boring made in 1913–14 at Eaton Bray Nurseries (owned by Messrs. Wallace) on the Chalk outcrop as shown on the map, showed the presence of pale Gault Clay below the Drift. The Lower Greensand was reached at a depth of 243 feet below the surface. We are indebted to Mr. Wallace, jun., for allowing us to examine samples of the cores in his possession and for communicating to us the details of this boring. Near Wendover, also, we failed to see the basement-bed of the Chalk. Finally, a visit was paid to the supposed outlier of Chalk at Billington, where the whole hill was found to consist of Gault Clay.

We conclude that to the south-east and south of Shenley Hill the basal bed of the Chalk was laid down in an area of deeper water than that in which the lenticles of gritty brachiopod-limestone of bed D at Harris's Pit were formed. This type of deposit must have had origin in shallower water, agitated by stronger currents. We must assume that these conditions prevailed in an area which included Shenley Hill, but did not extend to the present location of the outcrop; and that owing to the recession of the Chalk escarpment and the denudation of the outliers all traces of the bed in its normal position have been removed.

4. INTERPRETATION OF THE EVIDENCE.

The main points of our interpretation have already been stated in the foregoing description of the evidence, but it may be well to give a brief account of the succession of events which we believe to be deducible from the study of the sections at Shenley Hill. Our reading of the evidence may be conveniently considered under two headings: events during Cretaceous time and events during and since Glacial time.

A. EVENTS DURING CRETACEOUS TIME.

There is no reason to doubt that deposits of Lower Gault age at one time extended over the area now occupied by Shenley Hill.

Passage-beds from Lower Greensand to Gault, of *tardefurcata* age, are the highest strata at present exposed in this immediate neighbourhood, underlying the Upper Gault. Later beds became denuded away before the deposition of the Upper Gault. The Upper Gault rests discordantly upon these passage-beds and upon the underlying Lower Greensand, showing a thin basement-bed of mixed composition containing much coarse material. This débris includes relics of the destruction of the *tardefurcata* bed, in the shape of nodules and fossils. The active denudation accompanying the overlap resulted in the sweeping together of other remains from older strata then exposed, as may be inferred from some of the fossils obtained by the late Mr. Walker at Harris's Pit from rock-masses which comprised much material from this Upper Gault basement-bed.

During the progress of the transgression, deeper-water conditions soon supervened, as shown by the clays overlying the basement-bed. These were relatively unfossiliferous at first, and included a deposit of finely brecciated clay, apparently formed of materials derived from the destruction of some older clay. This passes upwards into marly clay containing the fauna characteristic of Bed IX at Folkestone. These relations indicate that the overlap probably coincides in date with the break marked by Bed VIII at Folkestone, in which are nodules containing a *remanié* group of fossils; hence the transgressive strata are to be classified as *rostratus* Gault. The section at Harris's Pit proves that still higher beds of the *rostratus* zone were deposited. They are of a marly character and contain an ammonite-fauna (the "*catillus*" fauna) represented in the Upper Greensand of Wiltshire, below the *Pecten asper* beds, and in the Upper Greensand of the Isle of Wight just below the Chert beds. These highest Gault strata are now only exposed at Shenley Hill in the inverted mass at Harris's Pit. If present *in situ* anywhere in the higher part of the hill they are concealed beneath the Drift.

The bed of green sand observed by Mr. Lamplugh to be intercalated locally between the brachiopod-bed and the Gault Clay, in the inverted mass, has yielded fossils which, so far as they are known, indicate definitely a zonal position above the Gault; and we consider that this bed may be correlated provisionally with the *Pecten asper* Greensand. The abrupt transition from the clay to the sand suggests that the junction between them may represent a line of non-sequence; a considerable thickness of strata in the more expanded arenaceous series of Wiltshire appears to be unrepresented here. The inconstant occurrence of this Upper Greensand bed, with rapid thickening, and the fact that where it is absent the basal Cenomanian bed with brachiopods is separated from the *rostratus* Gault only by a thin layer of ironstone of later origin, point to a denudation of the uppermost part of the Selbornian series prior to the deposition of the basal Cenomanian bed, with a corresponding degree of non-sequence. This period of denudation produced still more far-reaching effects in the region of the Cambridge Greensand, in parts of which, at least, the removal of much of the Upper Gault was also involved.

The next bed to be considered is the brachiopod-bed, which consists of isolated limestone-lenticles, forming the lowest part of the inverted mass. This affords ample evidence of its age and of the conditions under which it was deposited. Its indigenous fauna is that of the sub-zone of *Catopygus columbarius* at the base of the Cenomanian stage as understood in this country; and it has not been proved that the bed contains fossils derived from older strata. As already stated, the Lower Cretaceous species recorded by Messrs. Lamplugh & Walker from the brachiopod-bed were in all probability found in the basal bed of the Upper Gault, where they would occur as derivatives. It is improbable that the strata which formed the true source of these older fossils were exposed to denudation at the time when the basal Cenomanian deposit was laid down.

We have remarked upon the close similarity of the limestone-lenticles to the gritty limestone found in part of Northern France at the base of the *varians* zone. Captain W. B. R. King, who sent over specimens of this rock during the recent War, informs us that it occurs at Matringhem in isolated lenticles occupying hollows in a floor of Devonian sandstone. This compares closely with the mode of occurrence of the similar lenticles at Shenley Hill and adds strength to our inference that we have here a basement-bed of the *varians* Chalk, laid down during the period of early Cenomanian movement and transgression. No later deposit of Cretaceous age is preserved at Shenley Hill.

The above brief description of events during Cretaceous time explains much confusion in the account of the strata offered by Messrs. Lamplugh & Walker. The brachiopod-bed (D) of those authors was ascribed by them to the Lower Greensand. In reality it consists of rock-masses belonging to the basal bed of the Chalk and the basal bed of the Upper Gault. The idea of a "peculiar" faunal assemblage, founded on a collection of specimens obtained from the rocks of both zones, was bound to be erroneous, particularly in view of the fact that some Lower Cretaceous species were found which were not indigenous to either of these horizons. Mr. Walker's recognition of so many links with the Tourtia-faunas of the Continent, whichever local "Tourtia" it might be, now gains a new significance. Transgressive basement-beds formed under conditions of active erosion are likely to contain species derived from any fossiliferous stratum of earlier age exposed to denudation at the time.

B. EVENTS DURING AND SINCE GLACIAL TIME.

It is evident that before the advance of the ice-sheet the Upper Gault in the neighbourhood of Shenley Hill was capped in places by the remnants of the Upper Greensand, with the lenticles of basal Cenomanian age extending over both. It is impossible to say whether any of the Chalk Marl here had still survived the ordinary processes of subaerial denudation. So far as the overturned mass of strata is concerned, no Chalk Marl was present.

The inversion of the sheet of strata now seen in an abnormal order of succession at Harris's Pit must be regarded as an effect of the glaciation of the district. The elevation of the ground probably opposed an obstacle to the advancing ice-sheet,[1] with the result that a huge mass of *rostratus* Gault and its thin capping of later strata became detached, carried forwards towards the south or south-east and completely overturned upon a floor formed, on the lower ground, by the basal part of the Upper Gault. It seems improbable that such a large mass could have been transported far from its original site.

It is remarkable that there are so few signs of disturbance at the present base of the inverted beds; and although there is sufficient evidence of squeezing, disruption, and confusion in the present state of the topmost bed of the substrata, this is only such as might result from simple crushing, without any continued forward movement of the transported mass after it reached its new resting-place.

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[1] Compare remarks by H. B. Woodward, "The Chalky Boulder-clay and the Glacial Phenomena of the Western Midland Counties of England": GEOL. MAG., 1897, pp. 495–6.

We may suggest that the coherence of the clays and sands would be increased by freezing, and that the transported sheet of strata may have been moved very slowly into its new position while held firmly in the ice-stream, and deposited upon snow or snow-covered ice. The subsequent melting would proceed so gradually as to let down the mass on to its new substratum with a minimum of disturbance. It may have been at that time that the limestone-lenticles of the inverted upper surface of the boulder became forced down by pressure into the yielding material of the floor.

While no known agency except the movement of an ice-sheet is adequate to have produced the result now seen, a consideration of the exact *modus operandi* may be left to those who have had more experience in the study of glacial phenomena. Sir Archibald Geikie has commented on the difficulty of conceiving how extensive thin sheets of soft strata can have been ploughed out of their place and pushed forward.[1]

This striking example of glacial transportation falls into line with the similar instances along the tract of country to the north-east. There is the well-known mass of Cretaceous strata at Roslyn Hill Pit, Ely, discussed in papers by the late Osmond Fisher and by Professor T. G. Bonney;[2] while at Biggleswade, near Bedford, a mass of Ampthill Clay nearly 70 feet thick has been found incorporated in the Boulder-clay.[3] Numerous other examples of the transportation of large masses or "cakes" of Jurassic and Cretaceous rocks in the Midland area have been recorded by various writers.[4] We may also refer to the boulder of Cretaceous strata 240 yards in length at Leavad, in Caithness.[5]

It is impossible to say how far glacial erosion, subsequently to the removal of the inverted strata to their present position, may have reduced the thickness of the mass. It may be remembered, however, that the fauna found at the present top of the reversed beds of Gault shows that the whole of the Upper Gault in situ at Shenley Hill can have been little more than 40 feet in thickness. Hence it appears certain that in relation to its area, the whole mass must have been thin from the time of its detachment. Again, we prefer to leave a discussion of this purely glacial aspect of the problem to those who are better qualified to offer an opinion.

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[1] In a discussion on Mr. Home's paper, cited below, p. 381.

[2] O. Fisher, "On Roslyn or Roswell Hill Clay-pit near Ely": GEOL. MAG., 1868, p. 407. T. G. Bonney, "Notes on the Roslyn Hill Clay-pit": GEOL. MAG., 1872, p. 403. Also *Cambridgeshire Geology*, 1875, p. 69.

[3] H. Home, "On a transported mass of Ampthill Clay in the Boulder-clay at Biggleswade, Bedfordshire": Quart. Journ. Geol. Soc., vol. lix, 1903, p. 375.

[4] For references to some striking cases see H. B. Woodward, op. cit., 1897, p. 495.

[5] R. G. Carruthers, "On the occurrence of a Cretaceous Boulder of unusual size at Leavad, in Caithness": Summary of Progress for 1910 (Mem. Geol. Surv.), 1911, p. 80. D. Tait, "On a large glacially transported mass of Lower Cretaceous Rock at Leavad, in the County of Caithness": Trans. Edin. Geol. Soc., vol. x, pt. i, 1911.

We may refer once more, in conclusion, to one of the changes which have taken place within the beds exposed in Harris's Pit and in the base of the local Gault of neighbouring sections since the recession of the ice. This is the formation of conspicuous tabular sheets of ironstone, resulting from the growth of mineral segregations. The present appearance of these undulating bands seems to speak for their formation for the most part during some period of post-Glacial time remote from the present day. It is probable that the process of ferruginous segregation took place most actively during some distant time under wetter climatic conditions, when there would be freer percolation of waters beneath the surface. The overlying clay must be regarded as the source from which the iron was derived.

It is possible that the chief part of the masses of iron-grit in the upper portion of the current-bedded Lower Greensand were formed by similar induration during the same period. We have noted that in one place in Garside's Pit one of these large masses is merged with a thin tabular band of iron-grit at the base of the overlying Upper Gault; while in a neighbouring part of the section the tabular band retains its individuality and is distinctly separable from the sand below it. The segregation would occur mainly along the lines of more easy permeability. This is in agreement with the observed development of the tabular ironstone-bands principally along surfaces of discontinuity in the series; thus, at the unconformable junction between Lower Greensand and Upper Gault; at the base of the overturned mass of strata; and above the basal Cenomanian deposit, which we have shown to be in contact with the overlying beds along a surface of erosion, with some degree of non-sequence. The ironstone is also present along minor planes of dislocation. The more uniformly porous nature of the false-bedded Lower Greensand would permit a freer diffusion of the mineral substances concerned in producing the induration; hence the larger size and more irregular boundaries of the masses of iron-grit situated in those sands. The vitreous character shown in parts of these masses must be ascribed to secondary siliceous induration.

The above interpretation of the remarkable section at Shenley Hill differs in every essential particular from that put forward by Messrs. Lamplugh & Walker; but it is in accord, we believe, with all the observed facts and does not violate any established principle of zonal palæontology.

5. SUMMARY OF CONCLUSIONS.

We may summarize our chief conclusions as follows:—

(1) The brachiopod-bed of Shenley Hill, as described by Messrs. Lamplugh & Walker, who referred it to the Lower Greensand, is shown by stratigraphical and palæontological evidence to be of a composite character. Its constituent parts belong respectively

to the basement-bed of the Upper Gault and to the basement-bed of the Cenomanian stage, as understood by English geologists (sub-zone of *Catopygus columbarius*).

(2) The Cenomanian bed is present in the form of isolated lenticles of limestone. Although no comparable stratum can be found at the present outcrop, which has receded from the area where conditions produced this particular type of deposit, the bed has a close lithological counterpart in Northern France (Matringhem), where there is an almost identical bed at the base of the *varians* zone.

(3) At Harris's Pit the Cenomanian bed, an inconstant layer of Upper Greensand formerly seen above it, and an overlying mass of Gault Clay of *rostratus* age are in an inverted order of succession. There is a junction of erosion and non-sequence between the Gault and the Cenomanian bed.

(4) The normal unbroken passage from Lower Greensand to Lower Gault (*interruptus* zone) is shown south of Leighton Buzzard in more complete development than in other sections hitherto described in this country. The series here includes a sandy passage-bed of *tardefurcata* age (with the *Leymeriella*-fauna) overlain by *interruptus* clay, as in parts of the Continent.

(5) The Lower Gault has not been seen at Shenley Hill, where there is an overlap of Upper Gault upon the Lower Greensand. The basal bed of the Upper Gault is here of mixed and variable constitution, with much coarse material, containing relics of the denudation of the *tardefurcata* bed. It passes up first into clay, then into more marly clay containing the early *rostratus* fauna of Bed IX of Folkestone, the highest Gault as yet seen at Shenley Hill *in situ*. The hill forms an outlier of the upper *rostratus* beds.

(6) At Harris's Pit the overturned mass of strata rests upon the basal bed of the Upper Gault, with which the Cenomanian limestone-lenticles have become intermingled. In neighbouring sections a thin remnant of the overlying Upper Gault Clay is present in normal sequence.

(7) The fossils recorded by Messrs. Lamplugh & Walker as occurring in the brachiopod-bed, of alleged Lower Greensand age, came in part from the Cenomanian limestone and in part from the basement-bed of the Upper Gault. The earlier of these strata would be likely to yield specimens derived from the *tardefurcata* bed and from lower zones, thus accounting for the supposed intermingled character of the fauna of the brachiopod-bed.

(8) It may be roughly estimated that the overturned mass was originally some 250 yards in length, in north and south extension, and upwards of 150 yards in breadth; its westerly boundary has not yet been reached in the sand-workings.

(9) The inverted mass of strata became removed from its original site during the glaciation of the district, as in the case of the transported masses at Biggleswade, Ely, and elsewhere. It was probably derived from the higher ground to the north or north-west of its

present location, where the outlier at that time was capped by the basal Cenomanian bed, or by remnants of it.

(10) Thin ironstone-bands which form a conspicuous feature in the section at Harris's Pit are developed principally along surfaces of stratigraphical discontinuity. Their disposition within the strata of both the normal and the inverted parts of the sequence shows that they were formed by mineral segregation subsequently to the glaciation.

The present study emphasizes a lesson. Since the whole fabric of stratigraphy is built upon the determination of age-relationships among superimposed deposits, it follows that an essential of sound stratigraphical work lies in the full utilization of all available palæontological criteria. If these be neglected, the data for correct conclusions are incomplete, and the investigator may thus permit himself to be deceived by the apparent simplicity of a stratified series. The stratigrapher is too often dismayed by the complexities of palæontological classification and nomenclature; but the determination of the age of successive strata does not necessarily demand an excursion into this forbidding domain. It can usually be compassed without the naming of species. Nevertheless, some knowledge of the faunal characterization of zones, as well as familiarity with the principles underlying the right application of that knowledge, must always form part of the indispensable equipment for stratigraphical work. The trouble involved in the use of these means for age-determination, however irksome it may seem, can no more be evaded than that which must necessarily be taken in the study of lithological characters and relations, from which are deduced the conditions under which sedimentation has taken place.

In the case of a composite fossil fauna consisting of derived and indigenous elements, the criterion of age is to be sought among the zonally latest life-forms and not among the earlier ones. The determination of age is then based upon previous experience of uniformities, both as regards biological facies and zonal restriction. Its accuracy is thus directly proportionate to the known invariability of the faunal and chronological inter-relation.

The elementary truths embodied in these remarks have been brought home to us by many workers since the days of William Smith; in more recent years by the illuminating researches of Charles Lapworth, S. S. Buckman, A. W. Rowe, and other investigators; but there is perhaps no illustration of them more convincing than that afforded by the study of Shenley Hill.

Finally, we desire to express our indebtedness to those who have kindly given help in the present investigation; to Mr. Gregory Harris and Mr. George Garside, who permitted us to visit their sand-pits; to Mr. Henry Woods for a list of fossils in the J. F.

SYNOPTIC VIEW OF THE TWO INTERPRETATIONS OF THE SECTION IN HARRIS'S PIT.

Lamplugh and Walker.		*Kitchin and Pringle.*
		. . Lower *rostratus*-Gault, with fauna of Bed IX, Folkestone.
B = Lower Gault, *in situ*.	B	B = Upper Gault mass, inverted.
Inconstant greensand-bed at base = ? *Mammillatus* bed.		. . Higher *rostratus*-Gault with "*catillus*"-fauna of Upper Greensand of Wilts and Isle of Wight. Inconstant greensand at base = ? *Pecten asper* zone.
Contemporaneous iron-grit floor	C	. . Post-Glacial limonite-band, along lines of unconformity and non-sequence.
Fossiliferous top of Lower Greensand	D	. . Composite bed : basal Upper Gault *in situ*, basal Cenomanian inverted.
Contemporaneous iron-grit floor	E	. . Post-Glacial limonite-band, along line of unconformity.
	F	Lower Greensand of pre-*tardefurcata* age.
	G	
Beds C to H = Lower Greensand.	H	. . False-bedded Lower Greensand.

Note.—For convenience, the column of strata is not represented in true scale.

Walker collection at Cambridge, with notes on certain of these, and for the loan of specimens; to Mr. T. H. Withers for his report on the Upper Greensand cirripedes; to Dr. B. Pope Bartlett for reporting on rock-specimens and fossils of Upper Greensand and Cenomanian age submitted for his opinion; and to our colleagues Mr. C. B. Wedd, for many helpful criticisms, and Mr. W. Manson, for the skill and care with which he has prepared the drawings for our illustrations.

Carboniferous Fossils from Siam.

By F. R. Cowper Reed, M.A., Sc.D., F.G.S.

(PLATE II.)[1]

Introduction.

IN 1899 the Cambridge Exploring Expedition to the Malay Provinces of Lower Siam collected a few fossils and many rock-specimens at a place named Kuan Lin Soh, in the Patalung district. A small broken image of Buddha from the temple of Bah Nah containing some similar fossils was considered to have been quarried from the same beds, and it was believed that these specimens represented strata of Cretaceous age.[2]

In the following year a brief report on the same material was made by the late Professor T. McK. Hughes,[3] and he was led to regard the fauna as indicating the highest beds of the Carboniferous or the Permo-Carboniferous, basing his conclusions on the following rough determination of the fossils: "*Proetus* sp., encrinite stems and arms, several species of lamellibranchs and brachiopods, including at least one species of *Chonetes*, *Pleurotomaria* sp., and a cephalopod with horse-shoe lobes." Special attention was paid to the lithological characters of the rocks in which the fossils occurred, and two types were recognized by Professor Hughes: (1) a grit of varying coarseness without determinable fossils, and (2) a very fine rock composed almost entirely of silica, with practically no lime, but some alumina.

It is the latter rock which has yielded the organic remains here described, the coarser rock not having any recognizable fossils in it.

The fossiliferous rock is of a curious and uncommon character, having an argillaceous or even chalky appearance, though thin sections and chemical analyses prove that it is almost entirely composed of minute grains of silica. When fresh it is tough and hard, with rarely a shaly and usually a subconchoidal fracture. It is whitish in colour, but occasionally is stained yellow or pink. It becomes soft and pulverulent when weathered and more or less decomposed, with a chalky feel and aspect.

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[1] This Plate will appear in the March issue.

[2] Report Brit. Assoc., Bradford, 1900, pp. 393–8.

[3] Report Brit. Assoc., Glasgow, 1901, p. 414.

The fossils, which are scarce and mostly fragmentary, are in a poor state of preservation, consisting either of crushed internal casts or external impressions, with the shell sometimes retained as a thin film.

It was felt that a more detailed examination of the material than was given in 1900–1 might yield fuller and more definite results, and Professor Hughes accordingly entrusted me in 1915 with the task, as the specimens had been deposited in the Sedgwick Museum. A large number of fragments have been carefully broken open or split, and by this means it has been possible to augment to a considerable extent the list which Professor Hughes gave in 1901, and to fix with more certainty the stratigraphical position of the beds. The fauna proves to be of peculiar interest, and in the almost total ignorance of the geology of this district of Siam the following notes may be of value to future investigators in these parts.

Pronorites aff. *cyclolobus* (Phillips). (Pl. II, Fig. 1.)

The late Mr. G. C. Crick kindly examined for me the single specimen of a cephalopod in the collection which shows a suture-line distinctly, and he considered that the shell was referable to the genus *Pronorites* and allied to the Carboniferous species *Pr. cyclolobus* (Phillips).[1] Our specimen shows about the last quarter of the outer whorl and a portion of the body-chamber; four suture-lines are preserved. The more strongly marked horseshoe-shaped saddles and the blunter or even rounded second lateral and accessory lobes, and the fact that the first and second lateral saddles nearly touch respectively those of the preceding suture-line and overlap the bases of the preceding adjoining lobes, are features which distinguish it from the typical *Pr. cyclolobus*. The whole shell when perfect must have measured about 20–25 mm. in diameter.

Prolecanites (?) sp.

Some poor impressions of the exterior and some flattened imperfect internal casts of a goniatite may perhaps be referable to a species of the genus *Prolecanites* rather than to *Pronorites*, but the reference is uncertain. The shell was apparently discoid and laterally compressed with all the whorls (6–7) exposed in the wide, shallow, open umbilicus. The overlapping of the whorls appears to have been slight, but the outer whorl increases more rapidly in size than the inner ones, and there are some traces of a more complicated suture-line than in *Pronorites*. Perhaps *P. compressus* (Sow.)[2] and *P. mixolobus* (Phill.)[3] may be compared with it; the latter is

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[1] Phillips, *Geol. Yorkshire*, 1836, pt. ii, p. 237, pl. xx, figs. 40–2. Foord and Crick, *Cat. Foss. Ceph. Brit. Mus.*, pt. iii, 1897, p. 264, text-fig. 125, p. 261.

[2] Sowerby, *Min. Conch.*, vol. i, 1813, p. 84, pl. xxxviii. Foord & Crick, *Cat. Foss. Ceph. Brit. Mus.*, pt. iii, 1897, p. 252, fig. 121.

[3] Phillips, *Geol. Yorks*, pt. ii, 1836, p. 236, pl. xx, fig. 43; Foord & Crick, op. cit., p. 254.

recorded by Crick[1] from the Coddon Hill Beds of Devonshire, which are closely similar lithologically as well as faunistically with the Siamese deposit, and the same species is a characteristic one of the "Posidonienschiefer" of the Harz and of Geigen, near Hof. There is apparently another species of *Prolecanites* or more probably *Nomismoceras* represented in the collection, but it is too poorly preserved for determination.

Glyphioceras (?) sp.

One slab of rock contains many much-crushed casts and impressions of a subglobose cephalopod with a broad rounded back and large convex outer whorl, slowly increasing in size, but almost completely overlapping the inner whorls, which are exposed in a small, deep, umbilicus with rectangular (?) edges. A few widely distant concentric constrictions cross the outer whorl. This shell may belong to the genus *Glyphioceras* (cf. *Gl. mutabile* Phill.),[2] or to *Gastrioceras* (cf. *G* (?) *Kayseri* Loczy,[3] of the Carboniferous of China), but there is not sufficient of it known to determine its relations. Mansuy[4] has doubtfully recorded the genus *Glyphioceras* from the Carboniferous of Eastern Yunnan, but it is a well-represented genus in the "Posidonienschiefer" of the Harz.

Pleurotomaria (*Mourlonia*) aff. *conica* Phillips. (Pl. II, Fig. 2.)

There is one portion of a shell of a *Pleurotomaria* half imbedded in matrix and somewhat crushed, but it can be seen to have been a low trochiform shell of 4–6 whorls, rapidly increasing in size and with an apical angle of 70–80 degrees. Each whorl is rather sharply angulated at the band, which in the basal whorl is peripheral, but on the upper whorls is situated a little distance above the suture-line. The apical surface of the whorls is slightly excavated just above the band, but becomes gently convex near the suture-line. Below the band the umbilical surface of the basal whorl seems to have been strongly convex, but it is rather crushed and has a concentric fracture simulating a revolving ridge. The margins of the band are sharp and prominent. The surface of the whorls is crossed by strong, regular, transverse, curved striæ, which are of almost equal size and nearly equidistant, and they meet the band on the apical surface at about 30 degrees or less, but apparently are nearly at right angles to it below. Dimensions: height (estimated) about 17 mm., basal diameter about 19 mm. With regard to its

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[1] Crick, Quart. Journ. Geol. Soc., vol. lv, 1895, p. 652.

[2] Phillips, *Geol. Yorks*, pt. ii, 1836, p. 236, pl. xx, fig. 26. Crick, *Cat. Foss. Ceph. Brit. Mus.*, pt. iii, 1897, p. 181 (and references). Holzapfel, *Palæont. Abhandl.*, vol. v, pt. i, 1889, p. 29, t. ii, figs. 2–6.

[3] Loczy, *Wiss. Ergebn. Reise Szechenyi in Ostasien*, Bd. iii, 1898, p. 44, t. i, figs. 7, 7*a*. Schellwien in Futterer's *Durch Asien*, Bd. iii, Lief. i, 1903, p. 139, t. i, figs. 1, 2.

[4] Mansuy, Mem. Surv. Geol. Indochine, vol. i, fasc. ii, 1912, p. 87, pl. xvi, fig. 5.

affinities, this shell seems to resemble *Pl. conica* Phillips,[1] of the Carboniferous Limestone, which Mrs. Longstaff[2] thinks may belong to the subgenus *Trechmannia* rather than to *Mourlonia* sens. str. The figure of a shell named *Pl. vittata* Phill. by Holzapfel[3] also bears a considerable resemblance to our specimen, and we may also compare the species *Pl.* (*Mourl.*) *Cayeuxi* Mansuy,[4] described from the Dinantian of Eastern Yunnan.

Euomphalus cf. *subcircularis* Mansuy. (Pl. II, Fig. 3.)

Several specimens of small planorbiform shells, with an average diameter of about 8 mm., may perhaps be compared with Mansuy's *E. subcircularis*[5] from the Carboniferous of Eastern Yunnan, though there are many European species which may be allied. The shell is coiled in a flat spiral of 5–6 rounded whorls, nearly subcircular in section and increasing very slowly in size, with a submarginal carination on the upper surface dying out towards the mouth. The spire is rather sunken, being slightly depressed below the level of the outer whorl, and the open umbilicus is also concave. Rather strong concentric striæ cross the whorls.

Helminthochiton cf. *priscus* (Münster). (Pl. II, Fig. 4.)

There is one symmetrical sub-semicircular and subconical plate of a species of *Helminthochiton* measuring 6 mm. in diameter, which agrees in general characters with the anterior plate of *H. priscus* (Münst.) as described and figured by De Koninck.[6] The slightly raised small median apex projects a little behind the angulated posterior end, and from the apex there radiate on each side a pair of submarginal fine straight grooves separating low rounded ridges. A rather large crescentic shelly process or shelf projects at a lower level behind the posterior end of the plate, and is crossed by a narrow triangular fissure which is doubtfully an original feature.

Parallelodon aff. *corrugatus* De Koninck. (Pl. II, Fig. 5.)

There is one right valve of a shell which is referable to the genus *Parallelodon*, but like the other fossils it is badly preserved. In shape it is transversely rhomboidal; the inferior margin is gently sinuated; the posterior end is rounded-subtruncate; the beak is broad, low, obtuse, and situated at about one-third (or less) the length of the shell; and the surface is ornamented with very fine radial lines and concentric growth-lines, the latter becoming stronger near the margin. In length the valve is about 15·5 mm., and in height about 9·5 mm. It appears to be allied to *P. corrugatus* De Koninck, as described

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[1] Phillips, *Geol. Yorks*, vol. ii, 1836, pl. xv, fig. 22.

[2] Longstaff, Quart. Journ. Geol. Soc., vol. lxviii, 1912, p. 303.

[3] Holzapfel, *Palæont. Abhandl.*, vol. v, pt. i, 1889, p. 50, t. vi, fig. 14.

[4] Mansuy, op. cit., vol. i, fasc. ii, pt. ii, 1912, p. 89, pl. xvi, fig. 7.

[5] Mansuy, op. cit., vol. i, fasc. ii, pt. ii, 1912, p. 105, pl. ix, figs. 3*a*–3*d*.

[6] De Koninck, *Fauna Calc. Carb. Belg.*, vol. iv, 1883, p. 199, pl. l, figs. 37–48; pl. li, fig. 36; pl. liii, figs. 21–9.

by Wheelton Hind,[1] but the ornamentation is finer. We may also compare, as regards general shape, the Culm shell from Hagen, figured by Nebe[2] as *Macrodus* cf. *normalis* De Koninck.

Edmondia sp. (Pl. II, Fig. 6.)

One internal cast and external impression of a small oval shell measuring 10·5 mm. in length and 8·5 mm. in height has the anterior and posterior ends subequally rounded; the inferior margin is strongly arched, and the beak is obtuse, broad, and less than one-third the length of the shell from the anterior end. The surface is covered with strong subangular, rather unequal rugæ. It seems comparable to *Edmondia MacCoyi* Wh. Hind,[3] but has not such blunt extremities. Mansuy[4] has described a species of *Edmondia* from the Carboniferous of French Indo-China, but it does not seem to be identical with our form.

Allorisma (?) sp.

One imperfect right valve of an elongated shell which has a somewhat swollen and incurved beak and strong concentric rounded undulations of subequal size, directed slightly obliquely to the length of the shell, seems probably comparable with *A. sulcata* (Fleming).[5] The anterior end seems rather abruptly truncate, and the posterior end rather sharply rounded; there is a strong rounded umbonal ridge running down to the latter end, with a very weak, wide depression in front of it, crossing the shell to the inferior margin, which is faintly sinuated. The length of the shell is about 24 mm., and the height at the anterior end about 10 mm. Species of *Allorisma* have been recorded from the Upper Carboniferous of Sumatra.[6]

Protoschizodus (? ?) sp.

The occurrence of a species of this genus is suggested by some very imperfect casts too poor for precise identification.

Posidonomya Becheri Bronn, var. nov. *siamensis*. (Pl. II, Fig. 7.)

Shell obliquely suboval to subrhomboidal, posteriorly expanded and flattened, with a long, gently curved or nearly straight hinge-line, rather less than the length of the shell; posterior margin gently and continuously arched, meeting hinge-line at very obtuse angle; inferior margin more or less sharply rounded; anterior margin nearly straight, with weak, wide, shallow sinuation at base of long narrow triangular ear; hinge-line meeting anterior margin at about 75

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[1] Wheelton Hind, *Mon. Brit. Carb. Lamell.*, vol. i, p. 140, pl. x, figs. 16–19.

[2] Nebe, *Neues Jahrb. f. Miner. Geol.*, Beil. Bd. xxxi, 1911, p. 458, t. xiv, fig. 7.

[3] Wheelton Hind, *Brit. Carb. Lamellibr.*, vol. i, p. 329, pl. xxxvi, figs. 23–30.

[4] Mansuy, op. cit., vol. ii, fasc. v, 1913, p. 25, pl. iv, fig. 6.

[5] Wheelton Hind, op. cit., p. 422, pl. xlviii, figs. 3–11.

[6] Fliegel, *Palæontographica*, Bd. xlviii, 1901, pp. 108–9.

degrees. Body of shell very gently convex, sharply marked off from anterior ear; umbo acute, directed forwards, situated at about one-third length of hinge-line or subterminal. Surface of shell covered with strong regular, concentric undulations, triangular in section, of equal or subequal strength and size, becoming less regular on anterior ear and smaller and weaker on posterior portion of shell, with fine, straight, radiating lines crossing them in middle part of valves. Some fine concentric lines are also occasionally present on the undulations. Dimensions: (I) height (oblique), 30 mm.; length (parallel to hinge-line), 23 mm. (II) height (oblique), 80 mm.; length (parallel to hinge-line), 55 mm.

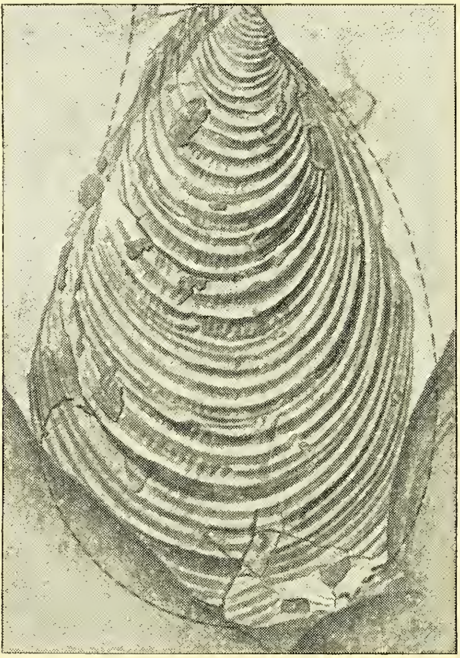

Fig. 1.—*Posidonomya Becheri* Bronn, var. nov. *siamensis*.

Remarks.—This is the species which occurs on the small broken image of a Buddha from the temple of Bah Nah. There are several more or less perfect examples of various sizes on it, and one shows both valves in juxtaposition and well preserved. The largest specimen is imperfect. The ornamentation is like that of *Posidonomya Becheri* Bronn;[1] but with regard to the characters of this genus there is considerable diversity of opinion. Zittel says it has no ears, whereas

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[1] Wheelton Hind, op. cit., vol. ii, p. 27, pl. vi, figs. 11–15.

Wheelton Hind says it has a rounded anterior ear and a compressed expanded posterior ear. The anterior ear is well seen in our complete specimen, which has both valves preserved, and in this example the ear seems relatively wider and larger than in the other specimens. In the largest shell the umbo seems subterminal, and the whole shell more elongated and less rhomboidal. Distortion often affects the shape of specimens of *Posidonomya*, and some of the difficulties and differences of opinion with regard to its characters result from this cause. There is a shell figured by De Koninck as *P. plicata*[1] which bears much resemblance to our specimens, and the Culm shells from North Devon, which Phillips[2] figured and described as *P. Becheri* and *P. lateralis* Sow. may also be compared. Diener[3] has referred some indistinct casts in the Anthracolithic beds of Spiti to this genus, but otherwise it does not seem to have been recorded from the Carboniferous of Asia.

The discovery of specimens of this shell at Kuan Lin Soh in a rock precisely similar to that of the image from Bah Nah, and their occurrence in the same rock as the rest of the fauna, fixes the age of the specimens in the image.

Posidonomya (?) cf. *radiata* Wh. Hind.

There is an imperfect impression of the greater part of the left valve of an obliquely ovate shell about 11 mm. high, with a gently convex surface marked by fine concentric lines and straight, radiating, broad ribs which are of rather unequal strength and width, being sharp, narrow, and strong near the posterior margin, but low and weak in the middle. So far as its characters can be determined, there is a resemblance of this shell to *Posidonomya radiata* Wh. Hind,[4] but the generic reference of this species seems open to doubt.

Pseudamusium cf. *prætenue* Von Koenen. (Pl. II, Fig. 8.)

There is one right valve of a species of a pectinoid shell represented in the collection by an internal cast and external impression, which resembles *Pecten prætenuis* Von Koenen[5] from the Culm of Germany. It measures 13 mm. in length and 10 mm. in height. In shape it is obliquely oval and very inequilateral; the beak is small, acutely pointed, directed forwards, and subanterior in position. The body is nearly flat and well marked off from the narrow elongated depressed posterior ear, which reaches about half-way down the posterior margin. The anterior edge of the shell is strongly arched forwards below the very small projecting anterior ear, which seems

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[1] De Koninck, op. cit., p. 182, pl. xxxix, fig. 8.

[2] Phillips, *Palæoz. Foss. Cornw. Dev.*, 1841, pp. 44–5, pl. xx, figs. 73–4.

[3] Diener, Perm. Foss. Centr. Himal.: *Palæont. Ind.*, ser. xv, *Himal. Foss.*, vol. i, pt. v, 1903, p. 138.

[4] Wheelton Hind, op. cit., p. 31, pl. vi, figs. 6–9.

[5] Von Koenen, *Neues Jahrb. f. Min. Geol.*, 1879, p. 329, t. vi, figs. 3, 4.

to have a deep byssal notch below it. The posterior margin of the posterior ear meets the hinge-line at a very obtuse angle. The surface of the body has a few strong, but low, concentric undulations and finer concentric lines. Wheelton Hind[1] considers Von Koenen's species to be identical with Salter's *Aviculopecten fibrillosus*, which he puts in the genus *Pseudamusium*. *Ps. auriculatum* (McCoy)[2] may also be compared.

Aviculopecten cf. *densistria* (Sandberger). (Pl. II, Fig. 9.)

The right valve of a small pectiniform shell, of which the impression and external cast are preserved, is practically indistinguishable from the Culm species described and figured by Von Koenen[3] as *Pecten densistria* Sandberger.[4] Our specimen has a height of about 6 mm. and a width of about 5 mm.

Actinopteria sp.

The impression of the left valve of a small shell, about 9·5 mm. in length, appears to belong to the genus *Actinopteria* or *Pteronites*. In general shape, position of beak, size of pre-umbonal portion, hinge-line, and convexity of body, it resembles the Scotch species, *Pteronites fluctuosus* Etheridge,[5] which Hind[6] refers to the genus *Actinopteria*, but the ornamentation is rather different, consisting in our specimen of numerous very fine, equidistant, regular radiating lines, more closely placed on the flattened posterior half of the shell behind the body, on which concentric growth-lines are also present.

(*To be continued.*)

Escarpments and Transverse Rivers.

By Henry Bury, M.A., F.G.S.

AT the end of a valuable paper on the superficial deposits to the north and north-west of London, Mr. Barrow[7] puts forward certain views as to the origin of escarpments and transverse rivers in the Chiltern Hills and the Weald which can hardly be allowed to pass unchallenged by those interested in the progress of geomorphology, for *unless there is more evidence in their favour than has yet been produced* these views are not progressive, but distinctly reactionary. To sum up the position in his own words (op. cit., p. 47): "Long after the cessation of all the bending movements

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[1] Wheelton Hind, op. cit., vol. ii, 1903, p. 106, pl. xvi, figs. 16–22.
[2] Ibid., p. 108, pl. xvi, figs. 23–7.
[3] Von Koenen, op. cit., p. 327, t. vi, fig. 2.
[4] Sandberger, *Rhein. Schichtsyst. Nassau*, p. 296, t. xxx, fig. 12.
[5] Etheridge, Geol. Mag., Vol. X, 1873, p. 345, Pl. XII, Fig. 1.
[6] Wheelton Hind, op. cit., p. 25, pl. v, figs. 8–12.
[7] Proc. Geol. Assoc., vol. xxx, 1919, pp. 1–48.

which produced the present structure of the Thames Valley, there was a fall of sea-level or a rise of the sea-bottom that brought the beds within reach of marine erosion. As a result the sea steadily ate its way far inland along the outcrops of the two masses of soft material, the Eocene beds and the Gault, leaving four projecting ridges, the two inner ones formed of Chalk, now the Chalk escarpments, and the two outer ones formed of Lower Greensand. In course of time the sea breached the Chalk ridges in a number of places (the majority of which are now windgaps), and through the gaps thus formed a great quantity of quartz-pebbles, etc., from the Lower Greensand were carried."

Those who are familiar—and what geologist is not?—with the old controversies of last century on the Denudation of the Weald, will recognize here a return, in all essential points, to the "marine" theory of the formation of escarpments and windgaps, which many of us imagined to have been completely and finally overthrown by the arguments of Greenwood, Ramsay, and other founders of the "subaerial" school. The hypotheses advanced by these writers were afterwards enlarged as our knowledge of river development grew, and in their improved form have been applied by Professor Gregory[1] and Professor W. M. Davis[2] to the very region with which Mr. Barrow deals, and it is therefore singular that he should discard these views without giving his reasons, and return to the old marine hypothesis without any comment on the difficulties thereby incurred.

It would take up too much space and serve no useful purpose to recapitulate all the arguments by which that hypothesis was opposed, but the two principal are—(1) that the postulated series of narrow, parallel arms of the sea following the strike of the strata has no counterpart in modern geography; (2) that it affords no satisfactory explanation of the origin of transverse rivers and their constant relation to the dip. Bearing these objections in mind, let us see how far the subaerial theory is invalidated, and a return to marine action compelled, by the new facts contained in Mr. Barrow's paper. After tracing the small quartz pebbles of the various drifts back to beds, now largely destroyed, of early (? Pliocene) age—the "Pebble Gravel" of Mr. Whitaker—he shows that this material must have come from the Lower Greensand, entering the Eocene region through at least one of the windgaps of the Chiltern Hills; and he also expresses the opinion that the Thames Valley was invaded by the sea at the same period. All this is quite compatible with the subaerial hypothesis, but that does not satisfy Mr. Barrow, who says,[3] "Without going into minute details, it will be sufficient for the present to say that this type of transit across the Gault could hardly have taken place unless that had an almost even surface

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[1] *Nat. Sci.*, vol. v, 1894, pp. 97–108; Geol. Mag., 1914, pp. 145–8.

[2] Geogr. Journ., vol. v, 1895, p. 145.

[3] Op. cit., p. 40.

and formed the bottom of a shallow sea, which passed through the gaps, breaking the Chalk escarpment up into a series of islands."

No evidence is offered that the sea ever reached the foot of the escarpment at all; and even if such evidence were produced, we should still ask for proof that it was the sea which formed the gaps, and not the gaps (as drowned river valleys) which admitted the sea. But it is as an explanation of the transference of quartz pebbles from the Lower Greensand to the Chalk that the hypothesis seems to have been framed, and here the interpolation of a narrow arm of the sea between the two lines of strata would seem to be rather a hindrance than a help to such migration, and it is submitted that unless very strong reasons against it can be given, the hypothesis of transference by transverse rivers is both simpler and more efficient. No less unsatisfactory is the account given of the origin of the transverse rivers themselves. We are told that[1] "When the elevation above sea-level" (of the sea-bottom in the Gault) "took place . . . local streams would tend to form, flowing through all the gaps". But this is by no means obvious. It has been held that the absence of longitudinal rivers running directly to the sea from the Weald is evidence against the marine origin of the escarpments and river system of that region; and similarly here we might expect that, if the sea entered from the east along the lines of weak strata, it would retreat in the same direction, thereby giving rise at once to a longitudinal drainage.

It must not be supposed that a subaerial origin for the windgaps is inconsistent with any influence of the sea in determining the drainage system of the South-East of England. On the contrary, it leaves untouched the question whether that system originated on an uplifted marine plain; and it is by no means opposed to the possibility that the sea, which seems at one time to have filled the London Basin, may, during periods of temporary depression, have made its way along the foot of the escarpments, as it seems to have done through the drowned valleys of the South Downs in Pleistocene times.

Nor must I be thought to wish in any way to depreciate the value of Mr. Barrow's work. It is only to some of his theoretical views that I take exception, because they appear to me retrogressive and unsupported by the facts so far before us. If there are other facts necessitating a radical change of view, it is to be hoped that they will soon be published.

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[1] Op. cit., p. 40.

Some Microchemical Methods.

By Alfred Brammall, B.Sc. (Lond.), F.G.S., Imperial College of Science and Technology, South Kensington

THE well-known and highly sensitive tests afforded by ferricyanide, ferrocyanide, and thiocyanate solutions for the detection of iron may be adapted, at the cost of a little trouble, to the microchemical investigation of certain rocks in thin section, as can also the equally well-known fusion test for manganese. The following methods have proved useful in special circumstances of the nature indicated in each case.

1. The necessity arose to determine the distribution of hydrated ferric matter in sediments affected by low-grade metamorphism, and to detect any marked tendency towards the accumulation of this substance in and about foci of recrystallization. Method applied to rock slices: The cover-glass having been removed, the slice is first cleansed of balsam, then polished, again cleansed, and warmed to evaporate any spirit retained by capillarity. Meanwhile, reaction papers are prepared: a piece of white drawing-paper, of area about twice that of the rock slice, is soaked in strong HCl and pressed between sheets of similar paper until it is no longer "wet"; an ammonium thiocyanate paper is prepared in a similar way. The acid paper is carefully laid upon the slice and covered with a strip of cardboard on which is laid a hot iron (2–3 lb. weight), care being taken not to shear the slice. After two or three minutes the weight, cardboard, and paper are carefully lifted from the slice, which is allowed to dry; the thiocyanate paper is applied (the same precautions being observed) and pressed, in the cold, to ensure good contact with the slice for a few minutes; it is then removed and the slice is again thoroughly dried before being examined in transmitted light. The distribution of ferric iron is revealed by a transparent blood-red stain of $Fe(CNS)_3$.

Potassium ferrocyanide may be substituted for the thiocyanate, but the blue coloration produced is due to an opaque pigment, which must be examined in reflected light. The thiocyanate stain has the advantage of transparency.

(*a*) The method has proved of especial value in the examination of "spotted" rocks; a typical case is described: In a Knotenschiefer from Andlauthal, Vosges, the spots, conspicuous enough in hand specimens, are differentiated from the matrix in thin section only by the following features: (i) abundant inclusions of opacite (carbon, largely); the inclusions in some spots traversed by pigment-rich bedding planes appear to have been derived, in part, from these planes, which are relatively free from this opaque matter for a short distance on each side of the spot; (ii) an irregular, brownish, transparent stain forming a peripheral zone; (iii) polarization colours sensibly lower than those of the matrix; some spots may be almost isotropic. On microchemical treatment the spots yield a pronounced stain, while the matrix takes only a feeble stain on the whole ; the peripheral zone is somewhat less responsive to treatment than the rest of the spot, but ultimately is stained throughout.

(*b*) The dark inclusions in chiastolite (andalusite) react very feebly, but the narrow opaque zone of matrix immediately surrounding the crystals usually reacts very strongly. The stains on the thiocyanate paper itself are worth examination.

(*c*) The alteration of chiastolite (andalusite), yielding structures closely resembling those observed in olivine altering to serpentine, often involves permeation of the mineral by iron-rich water impregnating the matrix ; the channels of alteration and their dust-filled dilations then react strongly for iron.

(*d*) Lamination in shales is frequently emphasized by narrow bands rich in opaque (carbonaceous) matter ; these layers are also usually rich in some easily soluble compound of " ferric " iron—a feature which may be, in part, at least, original, and possibly due to the incompatibility of iron with colloidal organic matter in solution, the two substances being precipitated together.

(*e*) Magnetite being much more easily soluble in HCl than ilmenite (or titanoferrite), it reacts much more readily by this test than does the latter. The reaction papers in this case should be prepared from blotting-paper, and should be slightly " wet ", so that the thiocyanate stain may spread somewhat by capillarity ; the stain on the thiocyanate paper itself should not be disregarded.

The rare occurrence of grains of native iron in certain rocks is more readily detected by applying a wash of slightly acidulated $CuSO_4$ solution, which coats the iron with a film of metallic copper, recognizable in reflected light.

(*f*) The method is also useful for demonstrating the distribution of chalybite in oolitic ironstones and less ferruginous oolites. Although chalybite is dissolved readily by HCl in the cold, the weight used to press down the acid reaction paper upon the rock slice should be hot so that the hydrated ferrous chloride first formed may be the more rapidly oxidized to the basic ferric chloride ; the acid is in sufficient excess to convert some of this basic compound to the normal ferric salt. As the products of reaction with HCl are hydrates and very hygroscopic, the application of the thiocyanate paper tends to produce smearing ; this is largely prevented by using reaction papers which are not " wet ", by drying the preparation in a hot atmosphere or a desiccator after each reaction, and by examining the preparation without delay.

It is well to supplement the thiocyanate preparation by two others, using potassium ferricyanide and potassium ferrocyanide on separate slices ; the blue pigment produced is examined by reflected light. The deliquescent $CaCl_2$ may be removed by first thoroughly drying the preparation (so as to " cake " the pigment) and then carefully washing it—the pigment remaining fixed.

On comparison of these preparations it is seen that (i) chalybite—often partly oxidized to limonite—may be located in a narrow peripheral zone of an oolith or in roughly concentric zones forming the greater part of the oolith, or (ii) chalybite may compose the entire structure. A nuclear mosaic of calcium carbonate granules may be the residue of an original aragonite oolith,[1] which is undergoing metasomatic replacement by chalybite, the latter being usually present in the matrix.

2. In the investigation of minute structures—stream lines and channels—in certain ottrelite-bearing rocks it was desired to determine whether the mineral matter infilling these channels contained an appreciable quantity of manganese. The test applied is described below. Such structures are very minute, and the results of the test require close scrutiny, otherwise significant spots may be overlooked and the reaction may appear too vague to be of much value.

A slice is ground down until it is about the thickness of a florin, and one side is polished. The slice is detached from the glass slip, cleansed of balsam, and dried (at about 150 degrees to desiccate the slice, and, if possible, promote fissures along the channels); it is then allowed to soak for several minutes in a hot saturated solution of $K_2CO_3 + KNO_3$, and dried. A thin wash of the hot solution is applied to the polished surface, the slice is again dried and laid on a tile, polished surface uppermost; this surface is subjected to the F.P. tip of the blowpipe flame for a few minutes, and when cold it is slightly polished to level (not to remove wholly) the thin veneer of "melt". The slice is then mounted (prepared surface downwards) in balsam, ground down as thin as possible, and examined by transmitted light. Before the blowpipe a slice which is too thin tends to buckle, and it may be necessary to break it up, after treatment, into two or more flakes to be mounted separately.

3. Bedding planes in chalk and limestone are often indistinguishable; nevertheless, extremely thin laminæ may be relatively rich in foreign matter (volcanic or meteoritic dust, for example), and these may be brought to light by the following method—approximating to a process of weathering: A specimen of the rock is ground evenly and polished in one or more selected directions, washed, and immersed in a bath of carbonated water. By differential solution, controlled by lack of homogeneity, bedding-planes, minute structures, etc., may be revealed. (Foraminifera rarely escape solution unless the water is very feebly carbonated; the process is then extremely slow.) The bath should be rocked occasionally, but very gently, otherwise delicate and significant structures may be obliterated.

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[1] Rastall, *Nature*, July 3, 1919, p. 359.

A Curious Fossil Charophyte Fruit.

By JAMES GROVES.

THROUGH the kindness of Mr. Henry Woods, I have had the opportunity of examining three blocks of limestone belonging to the Sedgwick Museum at Cambridge, which were collected by the late E. B. Tawney, from the "Chara Bed", Étage Oeningien, Upper Miocene, at Locle, Jura (Canton Neuchatel, Switzerland). The blocks contain a number of the remains of fruits of a species of Charophyte, which present a feature I had not hitherto observed, and to which I think attention may advantageously be drawn. Before describing this peculiarity, however, it will be desirable to say something as to the conditions of preservation in which such bodies are usually found.

In living species of *Chara, Lamprothamnium, Lychnothamnus, Nitellopsis*, and *Tolypella*, when the fruits are more or less mature, the five spiral-cells which form the sac of the oogonium often secrete a deposit of lime extremely fine and close-grained, almost porcelain-like in texture. The lime is gradually deposited on the inner wall of each spiral-cell, that is, on the side adjacent to the oospore, often only partially, but in its fullest development almost entirely, replacing the original protoplasmic contents of the cell. The lime-contents of the five spiral-cells combine to form a firm hard shell, known as the lime-shell, which envelopes the oospore, and is no doubt protective in character. When the fruit becomes dry and the soft part collapses, if the lime deposit is thin, each of the spiral-cells appears as a rounded furrow. The concavity of the cells decreases in proportion as the lime deposit thickens, becoming flat or even convex when the cell is completely filled. Neither the five cells forming the coronula nor the single stalk-cell secrete lime.

Apparently in almost all cases it is to the presence of such a lime-shell that we owe the preservation of charophyte fruits as fossils, and it is noticeable that the one living genus, *Nitella*, which does not produce a lime-shell, is not known in the fossil state. The remains of charophyte fruits, ordinarily found as fossils, consist of the sac formed by the five spiral-cells only, without either the coronula or the foot-stalk, and therefore correspond with the lime-shell. Occasionally the oospores are found in the sacs. We find the spiral-cells in the fossils in all stages of thickness, ranging from the very thin concave bands in some types, which I refer to *Tolypella*, to the thick convex coils found in some specimens of the *Chara medicaginula* type.

On the interior surface of some of the fossil oogonium sacs one comes across a layer of soft fine white lime of varying thickness, but usually much thinner than the hard darker outer shell. In the specimens of which I am writing it is in this inner layer of white lime that the unusual feature occurs in the shape of a tubular hollow, which follows the course of each of the spiral-cells, as shown in Fig. 1, *B*, *C*. I had previously assumed that the layer of white lime was simply a deposit, extraneous in origin, which had taken place between the oogonium sac and the possibly shrunken oospore. The presence of these uniform tubular hollows in Mr. Tawney's specimens, and the division of the white line into regular bands, as shown in the illustration, however, seems to point to an organic origin.

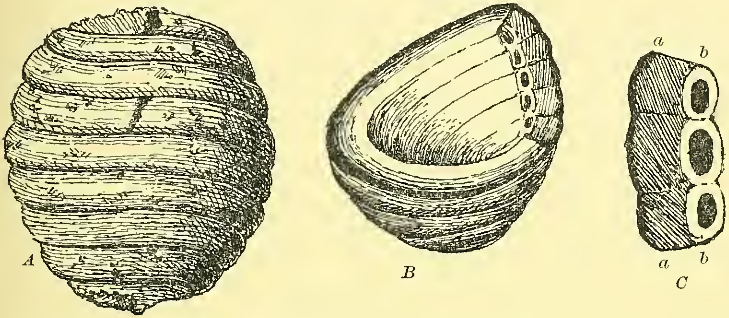

FIG. 1.—Fruit of fossil Charophyte from Locle, Switzerland. *A*. Nearly entire oogonium, × *circa* 31. *B*. Broken specimen, showing section of part of the wall of the oogonium and an internal layer of soft white lime with tubular channels, × *circa* 31. *C*. Transverse section (diagrammatic of three of the petrified spiral-cells forming the wall of the oogonium), *a a* with the corresponding bands of the white lime layer, *b b* having compressed tubular channels shown as black ovals, × *circa* 65.

I am at present unable to suggest any explanation of this problematic feature, and the main object of this note is to draw attention to its occurrence, in the hope that those having the opportunity of investigating freshwater deposits will keep a look-out for charophyte fruits, which may throw some light on the development in question.

I have not seen authentic specimens of *Chara Merianii* Braun, which is reported from the Miocene of Switzerland and Baden, but conclude from Heer's figures in *Flora Tertiaria Helvetiæ* that the specimens under consideration belong to that species.

REVIEWS.

Equidæ of the Oligocene, Miocene, and Pliocene of North America: Iconographic Type Revision. By H. F. Osborn. Memoirs of the American Museum of Natural History, New Series, Vol. II, Pt. I, 1918. pp. 217, with 54 plates and 173 text-figures.

THE work issued under the foregoing title is a systematic revision of the hundred and forty-six described species of Oligocene–Pliocene horses of North America, with reproductions of the original figures, new figures of many types, and a series of plates of comparative drawings. It is intended to clear the ground for President Osborn's long-looked for monograph of the Equidæ and is intentionally restricted to statements of fact with only that irreducible minimum of theoretical conclusions essential in such a work.

In the opinion of the reviewer it is the most impressive palæontological work which has ever been published. The short, absolutely clear, and workable generic and specific diagnoses, the simple and straightforward arrangement, the extreme lucidity of the comparative drawings, the abundance, perfection, and accurate dating of the material, inevitably leave the reader with an overwhelming feeling that here the mode of mammalian evolution is shown in detail for the first time, and shown in the best possible way by arranging the facts in order and leaving them to speak for themselves.

When the final monograph is published, with President Osborn's critical interpretations of the different phyla within each genus, and of the evolution of each part considered in detail by itself and in correlation with the rest of the structure, we shall have the most adequate material which can at present be made available for a critical discussion of biological theories of evolution.

Palæontologists and zoologists have been long acquainted with the series of generic stages leading up to *Equus*, as they have been established by the American palæontologists; but none except those who have been so fortunate as to see the American Museum collections can have had any conception of the completeness of the story, and even those who have handled that vast series could not previously appreciate the infinitely close gradation between the species of a single genus which occur at different horizons.

As the importance of palæontological material depends entirely on the fact that the relative ages of the species forming a series are known, President Osborn begins his monograph with a most useful account of the stratigraphy and correlation of the many localities of North America which yield horse remains. The whole series of North American Tertiary land deposits is now divided into zones on mammal evidence, and some progress has been made in correlating these with marine deposits. The extremely careful collecting carried out by the American Museum parties has established these zones on a firm stratigraphical basis, and has even allowed of a record of the position of individual specimens within their zone. Thus much of President Osborn's material fulfils in the highest degree the first demand of a palæontologist. Of the Oligocene genus *Mesohippus* eighteen species are described, the upper teeth of nine of which, figured in order of age, show a steady advance in structure by stages which are individually scarcely recognizable, until the latest form passes into the genus *Miohippus*, the line separating the two genera being of purely arbitrary position. The upper teeth of seven species of *Miohippus*, figured in order of age, show an exactly similar steady change, until the latest form *M. gemmarosæ* differs scarcely at all from the most primitive *Parahippus*, *P. pristinus*. From this form there is a complete structural passage to such advanced forms as *P. brevidens*, which differs very little from the earlier *Merychippi*, such as *M. isonesus primus*. Of this species there is a series of five mutants, in Waagen's sense, not that of de Vries, occurring in order in about 25 feet of sediments, the latest of which, *M. i. quintus*, differs much more in tooth-structure from *M. i. primus* than the latter does from the advanced *Parahippi*. More advanced species of the very complex genus *Merychippus* lead insensibly into *Protohippus*, *Pliohippus*, and *Hipparion*, and many stages of the later evolution of these genera can be traced in the material.

There are thus known about three dozen stages between the most primitive *Mesohippus* and the most advanced *Pliohippus*, and the gaps separating these stages are all of extremely small magnitude, so small that when more material is published they will inevitably disappear entirely, because the structures change steadily with time, and the size of the structural gap between two specimens depends on the time interval which separates them. The present work being concerned with type-specimens does not include those forms of intermediate structure which are not of specific or good mutational rank.

These steady changes in definite directions are shown not only in the teeth but in skull structure and proportions, and especially clearly in the interlocking relations of the carpals and tarsals.

The fundamental conclusions which, although they are never mentioned in the text, are forced on the reader of this monograph, especially by the comparative plates, are: that the evolution of the horses has proceeded steadily with time by the steady accumulation of changes of infinitely small magnitude, without or with only the extremely rare and unimportant occurrence of saltations: that the changes are steadily in the same direction until a character is fully formed and functional: that series of changes of identical character go on in distinct but parallel phyla, which may in some cases be traced through from genus to genus.

None but those who have handled similar material can have any idea of the vast amount of work of the highest class concealed behind the unpretentiousness of this superb monograph. President Osborn expresses his acknowledgments to his colleagues, Gidley, Granger, and Matthew, to the published work of many other American palæontologists, to Professor J. C. Merriam, to his assistant, Miss Ripley, and to the artists, Messrs. Oka and Yoshihara, and Mrs. Stirling.

This memoir represents the result of "team work" by eminent students fused into one by that palæontologist whose studies have gradually established those philosophical principles on which modern methods of palæontological investigation very largely depend. It provides a triumphant vindication, had one been necessary, of the soundness of the policy adopted by Professor Osborn of sending out on collecting expeditions year after year those palæontologists who are going to work up the material acquired. Only in this way is it possible to attain that certainty of horizon which is essential for satisfactory work. Had dependence been placed on the purchase of collections and on the sporadic gatherings of geologists, this work would have forever remained impossible, because the zonal classification, probably the most detailed and satisfactory one known, could not have been worked out and the horizon of any specimen would always have been open to doubt.

D. M. S. WATSON.

THE GRIMALDI CAVERNS.

LES GROTTES DE GRIMALDI (BAOUSSÉ-ROUSSÉ). Tome I, Fasc. IV: Géologie et Paléontologie (*fin.*). By MARCELLIN BOULE. pp. 237–362, pls. xxx–xli. Monaco, 1919.

PROFESSOR BOULE is to be congratulated on the completion of his important work on the remains of vertebrate animals found with man in the caverns of Grimaldi on the south coast of France. It is not merely a technical treatise on fossil bones and teeth, but also a general discussion of the Pleistocene mammalian fauna, of very wide interest. The final instalment deals with the Carnivora, Insectivora, Cheiroptera, and Rodentia, besides more fragmentary remains of birds, reptiles, and amphibians. It then ends with a summary of the results.

Professor Boule points out that the succession of a warm fauna (*Elephas antiquus*, *Rhinoceros mercki*, *Hippopotamus*, etc.), a cold fauna (glutton, ermine, marmot, reindeer, etc.), and then the modern fauna, is as clear in the low latitude of the French Riviera as in the rest of Central and Western Europe. He correlates the first (or Chellean) period with the third interglacial period of Penck, and the following (or Mousterian) period with the Würmian glacial episode of Penck. He adds maps showing the geographical distribution of some of the most important species of mammals, and in several cases he illustrates the relationships of the Pleistocene forms by elaborate genealogical tables. His observations on the lynx are especially interesting, for he shows that the extinct race of Grimaldi is precisely intermediate between the existing northern race and that still found in Spain.

THE SCHRAMMEN COLLECTION OF CRETACEOUS SILICISPONGIÆ IN THE AMERICAN MUSEUM OF NATURAL HISTORY. By Dr. MARJORIE O'CONNELL. Bull. American Mus. Nat. Hist., vol. xli, 1919. pp. 261, with 14 plates.

THE palæontologist soon learns to divide newly published matter into two categories, that which gives more trouble than the information offered is worth, and that which, by saving the reader trouble, aids him in acquiring the new knowledge it has to impart. A glance at the work under review leaves no doubt in which category it should be placed. While the amount of new information it contains may not be great, it is not likely that anyone wishing to gain a general knowledge of Cretaceous Sponges will consult this work in vain, or, having read it, will put it down without understanding how far our present knowledge of the subject goes, or without knowing what works to consult for further information.

But he will have learnt more than this. The trouble he is saved is the clearing away of unnecessary obstacles to knowledge, and not the trouble of taking pains. A glance at pp. 34–46 shows the ordeal to be undergone before you or I can become a good disciple of "Palæospongiology" (a blessed word, but a mealy mouthful). The terminology of spicules is a lacerating tangle of Amphitorns, Cricamphityles, Diancistras, and such like, from which one emerges only to come upon Ophirhabds (" long, smooth monaxons of irregular or snake-like curvature, generally tapering towards both ends "), with but a Tox (" bow-shaped spicule ") and a Labid (" spicule shaped like sugar tongs ") for self-defence—and there are more than a hundred of these thorny terms. But having mastered the spicular terminology and learned how to apply it—here is the test of its utility—the student of fossil Sponges may feel well equipped for further study, and may reasonably hope that the difficulties of the future will be considerably less than those already overcome. As a student, the complex terminology of types (pp. 99–101), following closely that of Schuchert and Buckman, but incidentally concerns him—this is mainly the curator's care; but he will welcome the detailed account of the European Cretaceous formations and the earth history of that epoch in Europe (pp. 47–97), finding here the means of correlating local terminology with stratigraphical terms of wider meaning. This, with a useful historical résumé of work on Sponges as a group, a geographical analysis of the literature of Cretaceous Sponges, a detailed systematic description of the Schrammen Collection in the American Museum of Natural History, and a bibliography of over two hundred works, finishes what is not merely an account of the Schrammen Collection in America, but much more, a very complete introduction to the study of Cretaceous Sponges as a whole.

It is hardly a just cause for complaint that the authoress's nationality appears in her writing. No Englishman who loves his land would refer, in speaking of the Dover district, to the " nearby cliffs along the Kentish coast " (p. 59). " Arkosic " (p. 81) is a strange word ; and " Cretacic ", however defensible, is both strange and ugly, and does not appear to be used in any sense different from the familiar " Cretaceous ", unless it is that Cretacic is American Cretaceous ; for " Cretaceous " is used, e.g. on pp. 52, 61, and 84, as well as in the title of the paper. " Disconformably " for " Unconformably " is unfamiliar. The following misprints have been noticed : " Morven " (p. 62) apparently should be " Morvan " ; on p. 72 " northern " is evidently a misprint for " southern " ; on p. 91 " *cornea* " should be " *carnea* " ; and on p. 154 " *Acorchordonia* " should be " *Acrochordonia* ". On pp. 150, 188, etc., " *Callopegma acaulis* " is written for " *C. acaule* ".

Since the book under review is ostensibly a work on Sponges, this is hardly the place to criticize in detail the stratigraphy expounded on pp. 47–97. But this otherwise admirable resumé is somewhat marred by the fundamental misunderstanding of the " zone ", apparent generally, but explicit in the remark (p. 52) " as in all such faunal work, the cephalopods, being pelagic, are considered the most reliable in the establishing of zones of limited vertical, but wide horizontal extent, for which reason the standard zonal subdivisions of the Cretaceous are based upon the Ammonites ".[1] Now, if I read its founder, Oppel, rightly, the " zone " is that sediment (if any) which was deposited during a given time in the earth's history. For convenience, it is named after a fossil occurring in it (not necessarily throughout it) in one locality (almost necessarily not all over the world). How, then, can a zone be referred to relatively as " of wide horizontal extent ", when a zone is necessarily worldwide ? And how can " zonal subdivisions " be " based upon Ammonites " when only their names are based upon fossils ? (It may also be remarked that to imply that Ammonites were pelagic is an assumption, even if it is generally true that other Cephalopods are and were.)

The authoress also appears to think that the zone of *Pecten asper* in the South-West of England is usually included in the Albian rather than in the Cenomanian, for on p. 57 she writes : " I shall include therein [in the Cenomanian] the Warminster fauna of the *Pecten asper* zone, since it would otherwise be difficult to compare with the figures for entire faunas on the Continent, where the

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[1] The division, by Grossœuvre, of the Chalk into zones named after Ammonites is given in tabular form, with correlations, on p. 50.

rocks containing *Pecten asper* are always recognized as marking the base of the Cenomanian." It served to emphasize the fact that the *P. asper*-zone is Cenomanian, that Jukes-Browne invented the term "Selbornian" for the Albian (including the zone of *Mortoniceras rostratum*) *plus* the *P. asper*-zone of the Cenomanian, for convenience in writing of the Upper Greensand of the South-West of England. Incidentally Jukes-Browne, not recognizing the zonal name as a mere label, quite unnecessarily altered the name of the zone from *P. asper* to *Cardiaster fossarius*, on the ground that *P. asper* was not commonly found in Devon and Dorset.

It might be supposed from a perusal of this work that in order to study the Cretaceous Sponges of North-West Germany, it is necessary to visit the collection in the American Museum of Natural History. But the British Museum possesses a very large collection of these sponges, named by Dr. Schrammen, and purchased from him some eighteen years ago. Specimens from this collection are figured on plate iii of the British Museum Guide to the Fossil Invertebrate Animals, a circumstance not noticed by Dr. O'Connell. The collection, though lacking many of the forms described in the work under review, yet contains many species not represented in the American collection. Considering, too, how well the British forms are represented, including as they do Toulmin Smith's types as well as those of the numerous species described by the late Dr. Hinde, the student of Cretaceous Sponges has all the material in the British Museum for ground-work, as well as for extended research, and armed with Dr. Marjorie O'Connell's handbook should be better equipped for this study than is the student of many another invertebrate group for his special task.

It may be gathered from what has been written how valuable a book Dr. O'Connell has produced—one which in its thorough treatment puts the new-comer at his ease by showing him exactly where he stands in relation to his subject. Such a work should be a stimulus to writers on other invertebrate groups and challenges imitation.

W. D. LANG.

A REPORT ON MAGNETIC DISTURBANCES IN NORTHAMPTONSHIRE AND LEICESTERSHIRE AND THEIR RELATIONS TO THE GEOLOGICAL STRUCTURE. By ARTHUR HUBERT COX, M.Sc., Ph.D., F.G.S. Phil. Trans. Roy. Soc. (A), vol. 219, pp. 73–135.

THIS paper is published as an appendix to the Magnetic Re-survey of the British Isles for the epoch January 1, 1915, by Mr. G. W. Walker. The earlier surveys of Rücker and Thorpe had revealed the existence of sundry areas of special disturbance, not evidently related to anything in the known geological constitution, and these disturbances are confirmed by the new survey. To elucidate their probable cause two areas were selected for more comprehensive examination, one lying between Melton Mowbray and Nottingham, and the other in the ironstone district of Irthlingborough. Additional magnetic observations were carried out by Mr. Walker, and Dr. Cox was commissioned to make a geological and petrological study of the two areas and to discuss the results, a duty which he has accomplished with much skill and judgment.

The problem is quite different from that presented by the much greater magnetic disturbances in the Western Isles of Scotland, which are manifestly due to permanent magnetization of rocks at the surface. Here, on the other hand, we have to do with induced magnetism, and Mr. Walker's observations indicate that the seat of the disturbance in Northamptonshire is at a depth of not less than 3,000 feet. The inference is that rocks of noteworthy magnetic susceptibility are in place at some considerable depth beneath this area, and that there is some irregularity in their distribution. Discussion of underground geology necessarily involves an element of the hypothetical; but the author is able to muster a sufficient number of data bearing on the question. He has made a list of all the rocks which are likely to occur beneath the district, and examined their petrographical characters, while determinations of magnetic susceptibility have been furnished by Professor Ernest Wilson. Dr. Cox points out that this property in different rocks is closely correlated with their content of magnetite. A granite containing only a little magnetite has a much higher susceptibility than a basic rock rich in iron in the form of silicates and in ilmenite.

The author ascribes the disturbances to the presence of dolerites as intrusions in the subjacent Coal-measures. Such dolerites are well-known in other parts of the Midlands, and they possess a higher magnetic susceptibility than any other rocks in that region. It may be mentioned that the investigation was undertaken primarily in the hope of detecting concealed iron-ores in this way, and the possibility should certainly be kept in view in relation to like magnetic disturbances elsewhere. Such cases as that of the Rosedale ore in Cleveland show that an isolated body of bedded magnetite-rock may occur in the midst of a formation which elsewhere carries only iron-oxides and carbonate. We have, however, no grounds for conjecturing such an occurrence beneath Northamptonshire, and intrusive dolerites seem to afford at least a good provisional explanation of the facts. The inferred irregularity of their distribution is attributed to faulting, and the author shows that the observed magnetic disturbances in this area correspond closely with faults which are mapped in the Mesozoic strata, and almost certainly extend into the underlying Palæozoic rocks. The disturbances near Irthlingborough can be referred to the Jurassic iron-ores of the district, which pass from ferrous carbonate in the interior into hydrated ferric oxide at the weathered outcrop, with a consequent diminution in magnetic susceptibility.

A. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

December 17, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the chair.

In the absence of the author, the following paper was read by Mr. R. D. Oldham, F.R.S., V.P.G.S.: "A Rift-Valley in Western Persia." By Professor S. James Shand, D.Sc., F.G.S.

Asmari Mountain, near the oilfields of Maidan-i-Naftun, in the Bakhtiari country of Western Persia, is an inlier of Oligocene limestone among the beds of the Fars System (Miocene), the latter consisting, in the lower part, of bedded gypsum with intercalated shales and a few thin limestones. The mountain is a whale-back, 16 miles long and 3 miles wide at the middle, formed by a simple symmetrical anticline plunging at both ends. The north-western end plunges rather steeply, and shows no abnormal structures; but at the south-eastern end the fold has collapsed along its length for a distance of 3 miles, letting the gypsum beds down into a trough in the limestone.

This trough is bounded by two main faults hading north-eastwards and south-eastwards respectively, with an average hade of 20°, and marked by steep escarpments. The northern scarp, which lies practically along the axis of the anticline, is at one point 500 feet high; but the southern one, being low down on the flank of the anticline, is much less conspicuous. Besides these main faults there are at least three other big faults parallel to them, which produce minor scarps within the valley; the valley-floor thus descends in terraces towards the south-west, besides having a general south-eastward inclination of some 10°. Uphill, towards the crest of the mountain, the downthrow of the limiting faults diminishes gradually to zero, and the valley dies out on the broad top of the anticline. Downhill, towards the plunging nose of the anticline, the trough is closed abruptly by a cross-fault nearly at right angles to the anticlinal axis. The length of the whole trough is 2½ miles, and its width half a mile.

The northern boundary-fault at its maximum has a downthrow of about 500 feet, the parallel faults range from 150 to 200 feet, and the cross-fault throws about 100 feet.

The gypsiferous beds which once completely filled the trough have been partly removed by erosion, clearly revealing the fault-walls in the lower part of the valley. These fault-scarps in their lower portions are remarkably fresh, and show the smoothed and fluted surfaces produced by the friction of the sliding faces.

The drainage of the faulted region is curious in several respects. The only perennial stream that traverses the valley cuts sheer across it from side to side. Rising in the gypsum beds on the north-eastern flank of the anticline, the stream turns south-westwards, and cuts right through the limestone in a deep cañon; the latter breaches the northern fault-scarp where the downthrow is greatest, and from here the bed of the stream lies in the gypsum of the valley bottom, except for a short stretch between two faults, where the limestone floor is again exposed to view. The stream finally breaks through the southern limestone wall, and so makes its escape from the valley.

These conditions imply that the river assumed approximately its present direction when there was a cover of gypsiferous beds over the whole area, and that, although younger than the initiation of the faulting, it is older than the sculpturing of the inside of the fault-trough. The eastern end of the trough is again tapped by another and smaller stream with a precisely similar development.

It might be surmised from the excellent preservation of the fluted surfaces on the fault-scarps that the last movement took place at a very recent date, but the behaviour of the river in crossing the scarps does not favour this supposition. The succession of events appears to have been as follows:—

(1) Formation of the trough with gypsum-infilling by partial collapse of the anticline.

(2) Levelling of the gypsum surface and development of a stream across the position of the buried trough.

(3) The stream, cutting down through gypsum, discovers the faults, etches them out, develops subsequents along them, and thus gradually eats out the gypsum filling the rift, until the present topography results.

January 7, 1920.—Mr. G. W. Lamplugh, F.R.S., President, in the chair.

1. "On *Syringothyris* Winchell and certain Carboniferous Brachiopoda referred to *Spiriferina* D'Orbigny." By Frederick John North, B.Sc., F.G.S.

This paper is the outcome of a suggestion made in 1913 by Professor T. F. Sibly, who pointed out the desirability of an attempt to remove the uncertainty which had hitherto existed in the naming of the British species of *Syringothyris*, and of the Carboniferous Spiriferids possessing a lamellose surface ornament, which it was customary to refer to *Spiriferina* because there was no other genus for their reception, although it had long been recognized that few, if any of them, really belonged to that genus.

After indicating the exact sense in which certain frequently occurring terms are used, and reviewing the history of previous research, the author discusses the history in Avonian times of the genus *Syringothyris*, and suggests a classification of its species.

Variations due to time, to environmental conditions, and to distribution in space, are recognized, and distinctive names are given to the mutations characteristic of certain horizons.

The syrinx (it is suggested) was a special arrangement called into existence to control the direction of and to support the adductor muscles as the area of the shell increased in height. It, and the transverse plate to which it was attached, originated as a modification of an apical callosity such as existed in many Spiriferoid shells. It was initiated in Middle Devonian times, and reached its acme early in the Carboniferous Period.

All known species of *Syringothyris* have the fold in the brachial valve, and the sinus in the pedicle-valve, smooth. Species such as *S. distans*, in which the fold and sinus are plicated, do not possess a syrinx, and are incorrectly referred to *Syringothyris*.

The form described by McCoy as *Spirifera laminosa* is referred to a new genus, since it has neither the punctate shell-structure of *Spiriferina* nor the internal characters of *Syringothyris*. The genus is represented in the Lower Avonian by mutations of the species *laminosa* McCoy, and in the Upper Avonian by the species *subconica* Martin.

Syringothyris and *Spiriferina* are in no way related, either morphologically or phylogenetically.

The small Carboniferous shells that have hitherto been referred to *Spiriferina* include two types characterized by external differences. Of these two types, one, in which there are numerous ribs and a relatively large rounded fold and sinus, is relegated to a new genus; while the members of the other type, which include shells with a few large angular ribs, are for the present retained in *Spiriferina*, although the type-species of that genus was derived from the Lias The subdivision here suggested for the Carboniferous forms will, it is believed, prove to be applicable to the later species also.

2. "Jurassic Chronology: I—Lias. Supplement 1, West England Strata." By S. S. Buckman, F.G.S. (Read in the absence of the author by Dr. W. D. Lang, M.A., F.G.S.)

In this communication the following points are discussed:—

(1) The Ammonite and some Brachiopod faunas of the Lias of Gloucestershire and Worcestershire.

(2) A method of faunal plotting as an aid to faunal analysis.

(3) That in the collection, analysis, and comparison of faunas, the following causes of failure have to be considered: Stratal, Depositional, Faunal, Dispersal, Exposure, Collection, Arrangement, Nomenclature, Fossilization, Preservation, Extraction, Zonalization, Publication; but several of these are not applicable to results derived from the investigation of limited areas.

(4) The evidence appears not only to support the conclusions of the author's former paper, but to show that in certain cases a fuller sequence of faunal episodes may be required.

(5) The fauna of small Ammonites in these Liassic beds, especially that of small *Schlotheimiæ* at Gloucester, suggests comparison with the faunas of Hierlatz and Spezia. The use of technical terms for different sizes of organisms, especially for small forms, is briefly illustrated.

(6) It is suggested that the strata and faunas of these Continental

localities are not so exceptional as they appear to be at first sight; and that English localities may be studied with advantage, in comparison with and explanation of the features of these Continental deposits.

(7) It is found that the preserved strata of the Gloucestershire–Worcestershire Lias under consideration happen in the main to be deposits of dates when the living Ammonites were rather small; while there is faunal failure and presumably stratal failure at the times when large Ammonites flourished. The converse phenomena are mainly illustrated by North Somerset deposits.

(8) The times when large and small Ammonites lived appear to follow one another like waves, illustrated even in a short table of Liassic deposits.

(9) As a result of the investigations connected with this paper it seems to be advisable, for recording purposes at any rate, to make further subdivisions in the scheme set forth in the author's former paper.

EDINBURGH GEOLOGICAL SOCIETY.

November 19, 1919.—Mr. E. B. Bailey, M.C., B.A., F.G.S., President, in the chair.

1. "Notice of a Shrimp-bearing Limestone in the Calciferous Sandstone Series near Granton." By D. Tait, H.M. Geological Survey.

This is a new fossiliferous locality, which is exposed between tide-marks near Muirhouse, about midway between Cramond and Granton. The chief feature of this bed lies in the remarkable abundance of fossil shrimps which it contains, some of which may be new species. It is 18 inches thick, but is not a solid bed. It is composed of thin bands of limestone with partings of shale. It varies in thickness, and the individual bands, which are finely laminated, have minutely wrinkled surfaces and shrinkage cracks due to drying.

What is probably the same band is exposed 4 feet above the sandstone of Granton (Sea) Quarry, and again in Granton (Land) Quarry. The horizon of this band is, therefore, low down in the Granton Sandstone Series.

The fossils obtained from the limestone to this date are *Orthoceras*, *Nautilus*, *Estheria*, at least three species of shrimps, and the fishes *Rhadinichthys brevis* Traq. and *Eurynotus crenatus* Agassiz. The fishes were determined by Dr. Smith Woodward of the British Museum.

The lithological description of this bed at Granton, though it is peculiar, applies exactly also to the well-known shrimp limestone at Cheese Bay near Gullane; this and the similarity of their fossil contents tempts one to correlate them with each other. But Dr. Peach says the species of shrimps found in the Granton Bed are different from those found at Gullane, and the Gullane Bed has been placed on the horizon of the Wardie Shales, while the Granton Bed is certainly in the Granton Sandstone Series immediately below.

2. " Note on a Find of Manganese Ore in Dalroy Burn, a Tributary of the River Nairn, Inverness." By Thomas Wallace, Inverness.

Mr. Wallace gives a general description of the district, illustrated by a map and section, showing the positions in which manganese ore was found. The chief locality is in the burn near the farm of Dalroy. The ore is there found as a band of possibly 3 feet in thickness, lying immediately under the Old Red Sandstone Conglomerate, and resting on the Gneiss below. The rock contains 30 per cent manganese oxide. Besides the ore in situ, many fragments were found in the burn, and also in the fields and at Clara Schoolhouse to the west.

3. " Exhibition of the Rhomb-Porphyry Boulder from Portsoy, Banffshire." By H. H. Read, H.M. Geological Survey.

This boulder of typical rhomb-porphyry was found between tide-marks in a cove about 50 yards west of Portsoy Gasworks. From the direction of ice-flow in Banffshire it was concluded that transport by Scandinavian ice was extremely unlikely. The possibility of transport by floating ice calved from the main Scandinavian ice front, during a period in which a narrow reach of open water lay between the Scandinavian and Scottish ice-sheets, was suggested, but the equal possibility of human transport as ship's ballast was also admitted.

December 17, 1919.—Mr. E. B. Bailey, M.C., B.A., F.G.S, President, in the chair.

" The Ayrshire Bauxitic Clay." By G. V. Wilson, B.Sc., F.G.S.

The high refractory character of the Ayrshire Bauxitic Clay was discovered early in 1916. A sample previously collected by Mr. E. M. Anderson from the exposure on Saltcoats shore had been analysed with the hope that the rock might be a bauxite. The result of this analysis showed that the material was rich in alumina, but mainly in a combined state, and so not available for use in the manufacture of aluminium. On consideration, it seemed possible that a rock containing such a high percentage of alumina as 47 per cent might possibly be of use as a refractory, and a small specimen from the locality was sent to Dr. Mellor, of Stoke-on-Trent, by Mr. W. Douglas, of Kilwinning. A test made on this sample gave the unexpectedly high refractory quality of over Seger cone 35 (1770° C.).

About the same time the late Dr. C. T. Clough was working on beds of similar age and character near Kilmarnock. He had specimens collected, and bore the expense of a series of tests by Dr. Mellor. The results, however, showed that the samples taken were not nearly so refractory as the material from Saltcoats.

The clay occurs at the top of the Millstone Grit Series, which in North Ayrshire consists mainly of a suite of basic lava-flows, with occasional interbedded fireclays, or of ganister-like sandstones. The lava series varies from 5 to 70 fathoms in thickness, and usually rests on another fireclay, "the Monkcastle Clay," which is not bauxitic.

The upper members of the lava series are often much decomposed, and often pass almost insensibly upward either into beds of poor ironstone or of bauxitic clay.

The clay varies in colour from almost white, through shades of grey, pink, yellow, or brown, to jet black; in hardness from that of a compact limestone to a faky blaes; and in texture from a compact, practically non-porous rock, with a conchoidal fracture, to an almost normal high-grade fireclay; but as yet it has never been met with in anything approaching to a plastic condition.

In some cases it is seen to be a distinct and separate deposit, but in others it appears to represent a metasomatic replacement of a pre-existing rock. Many of the detrital samples show a beautiful development of oolitic structure, which in the main appears to be due to the rolling about of small fragments (sometimes even of broken oolites) on the bottom of a shallow pool of water, which was capable of depositing aluminous material. In a few cases a somewhat similar structure has been developed by concretionary action.

The alumina content varies from 26 per cent to 52 per cent; and in varieties containing more than 39 per cent (i.e. the amount of Al_2O_3 in kaolin), practically all the silica is in the combined state as that material. The mineralogical nature of any excess alumina which might be present has not as yet been determined.

In many ways the bauxitic clay is similar to bauxite, but differs from it in that the alumina is mainly in a combined form and not free. There can be little doubt, however, that the two materials have similar origins, and it appears likely that the close of the Millstone Grit period in North Ayrshire took place under damp tropical conditions; with the result that the land surface of the lava-flows was subjected to a peculiar type of decomposition known as bauxitization or lateritization, which in this case seems to have been accompanied by reducing conditions, brought about by the decay of large quantities of vegetable matter, producing such gases as carbon dioxide and marsh gas, and thus causing the iron in the minerals present in the basalts to be reduced to a soluble ferrous condition, and thus removable by percolating waters. The alumina also seems to have gone into solution, and from the absence of any form of free silica in the deposit it appears possible that the two were combined, forming a soluble hydrous silicate of alumina, which was capable of depositing kaolin and free alumina.

January 21, 1920.—Mr. E. B. Bailey, M.C., B.A., F.G.S., President, in the Chair.

1. "Evidence of the Retreat of an Ice-sheet to the South-East of Edinburgh." By D. Anderson, M.A.

Mr. Anderson referred to the work of Professor Kendall and E. B. Bailey on the glacial channels in East Lothian, the principle of which was that of marginal drainage along the edge of a retreating ice-sheet. Mr. Anderson was led to look for similar evidence in Midlothian. He then described the area which he had surveyed, which consisted of two ridges and the three valleys or stream-courses by which these were marked out. The first is the Liberton–Craigmillar Ridge and the second that of Gilmerton; the stream-courses being those of the Braid Burn, the Burdiehouse Burn, and, more remotely, the North Esk. After describing the main surface features of the district by reference to the map, and an allusion to the contour of the main roads which cross the ridges in a south-easterly direction from Edinburgh, he pointed out the geological structure of the Liberton Ridge as belonging to the Upper Old Red Sandstone System, while the Gilmerton Ridge consisted of the coal and limestone series of the Carboniferous. The series of glacial channels crossing the ridges were then described. A well-marked one to the south-west is the Longloan Channel, so named from a place which stands on its west edge. The height here is 450 feet, consequently when the cutting began the impounding ice-mass must have stood somewhat higher, and since Blackford Hill, the Braids, Craiglockhart Hill, and Corstorphine Hill all reach 500 feet, these heights may have risen like low islands above the surface of the ice-lobe, somewhat back from its edge. The contour of the Longloan Channel, as well as that of the others, was indicated by sections kindly prepared by Mr. Mathieson of the Ordnance Survey from measurements taken with this special end in view. The depth here was 33 feet, and the width 303 feet. Some four more channels on this ridge were similarly described, the direction in which they were taken being from south-west to north-east. After having referred to certain other glacial phenomena on the Gilmerton Ridge in connexion with the channels, he concluded by referring to one which crosses the Liberton–Craigmillar height just at the place where this is crossed by the Old Dalkeith Road. The lobe of the retreating ice-sheet, which was the cause of the glacial channels described, probably occupied the bed of the present Forth and constituted the impounding barrier at the different heights; and was, of course, the mere shrunken remnant of a vast ice-sheet that had once enveloped the whole country.

2. "The Principles that regulate the Distribution of Particles of Heavy Minerals in Sedimentary Rocks, as illustrated by the Sandstones of the North-East of Scotland." By Dr. Wm. Mackie, M.A. Communicated by Dr. R. Campbell.

Such characters as size, specific gravity, chemical stability, and solubility all influence transportation and subsequent preservation of the mineral grains which go to form sediments. The manner of disintegration of the parent rock is of importance in determining the initial size of grains derived from it. The agent of transport, whether wind or water, takes charge of the loose grains, and sorts or mixes, preserves or destroys, according to its particular attributes of speed, temperature, and composition. Solution after deposition may sooner or later remove the far-travelled remnant. These and other principles were passed in review. Finally, a most interesting discovery was announced. All the way from Sutherlandshire and the Orkney Isles, in the north, to Yorkshire, in the south, sandstones and grits, ranging in age from Pre-Cambrian to Triassic, are apt to yield deep purple-coloured zircon in beautifully rounded grains; and this zircon has almost certainly been derived from some area lying outside of Britain.

CORRESPONDENCE.

THE AMMONITE SIPHUNCLE.

Sir,—In his interesting paper on the "Ammonite Siphuncle" in last month's Geological Magazine, Dr. A. E. Trueman rejects my suggestion (adapted after Pictet, etc.) that *a* (not *the*) function of the siphuncle in *Nautilus* was to afford a means of attachment of the animal to its shell. I would gladly welcome a theory that explains all the facts (which my suggestion does not do), but, unfortunately, Dr. Trueman does not offer a better explanation. He considers as more reasonable, however, the opinion of Drs. Foord and Woodward, who had suggested that the siphuncle was "of more importance in the young, perhaps then serving for attachment . . ." Thus, it may be attachment after all, and the objections that I would adduce against my own explanation, Dr. Trueman does not mention, namely, (1) that histologically the siphuncle of *Nautilus* is not a ligament, and (2) that the concentric muscle-lines indicate a gradual shifting of the shell-muscles during growth, concurrently with the secretion of gas. But, while perfectly willing to admit that in some primitive Nautiloids and also in the young of Ammonoidea (which then had simple septa) the evidence of attachment is, perhaps, stronger, I do not think that we are justified in assuming, as Dr. Woodward did, that the function of the siphuncle is performed, in the adult *Nautilus*, by the shell-muscles, as though these structures were not present in the young. Nor is there any evidence that the siphuncle is of less functional importance in the recent *Nautilus* than in a homœomorphous Silurian shell, or again in a Cretaceous Ammonite than in a Devonian Goniatite.

My contention was that during a forward move of the shell-muscles (the peculiarly pitted appearance of the scars in some fossil forms suggests a more secure attachment than in the living *Nautilus*) some additional means of attachment was useful, and that this was supplied by (but not the only function of) the penetrating fibres of the folded margin in Ammonoids and the siphuncle in *Nautilus*. Since the animals with severed siphuncle mentioned by Willey were attached to their body-chambers by means of the shell-muscles (Willey performed the operation at the base of the body-chamber, behind the annulus) there was, of course, no danger of the animals falling away from the shells. Truncation of the septate portion is not uncommon in fossil forms, and in some *Discoceras* (probably on adaptation to a purely crawling mode of life) all the cameræ were cast off and the shell of the adult (and not till then propagating) animal consisting of the body-chamber only. This merely proves that there was no further formation of septa, and the shell-muscles became permanently attached to the shell-wall and held the animal fast, but it is not evidence against my view.

On the other hand, it could be argued that owing to its constriction at the septal necks, the siphuncle of even a truncated *Protobactrites* or of an *Amphoreopsis* (with only a few cameræ) might have been sufficient for the purpose of attachment. Only here it must be admitted that if this notching of the siphuncular tube is looked upon as a strengthening feature for such attaching purposes, then a similar function must also be assumed for Ammonoidea. In some large sections before me (*Parkinsonia dorsetensis*, *Phylloceras heterophyllum*) this constriction at the septal neck is more apparent than in the (dried) shells of the recent *Nautilus*. On the other hand, inflation of the endosiphotube (between successive endosiphosheaths) and of the ectosiphuncle (between the septa) is found in many fossil *Nautili* (I am not referring to the actiniform siphuncular structures), and the separation of these from the cameræ by either thick mineral deposits or by continuous septal necks does not favour an assumption of gas-secretion by the vascular siphuncle.

My opinion certainly was not based on the interesting, if unscientific, account quoted by E. A. Smith. A reference to this was given merely to show how the shell-muscles in the living *Nautilus* became detached. But the origin of the siphuncle as a constriction of the viscera, and the various structures in the multitudinous developments of the order Nautiloidea, especially the more primitive forms (*Piloceras* and the Proteroforms of the *Cameroceras–Vaginoceras* series) seemed to me most instructive, as also the transitions from the endosiphuncular structures to the later ectosiphuncle of e.g. *Baltoceras*, which genus Hyatt placed as the first of his family Orthoceratidæ. I collected a number of very interesting Lower Ordovician Cephalopoda in Newfoundland some seven years ago, but their description is delayed because it entails a revision of the classification of the whole order Nautiloidea. I may also mention that the blackness of the outer coat of the siphuncle in *Piloceras* (the specimens are preserved in a dolomite, exactly like the Durness fauna) and the dark outer layer of the siphuncle in certain forms of *Vaginoceras* suggested a different chemical composition, but I could not get a molybdate precipitate. My observations did not support any of the previous explanations of the function of the siphuncle, including those given by such careful observers as Professor Blake and Dr. Willey, though there was no need to go into them all again.

I may also mention that I would consider the typically regular septation of Cephalopoda as a whole and formation of chambers filled with gas (as contrasted with the tabulation, etc., in other tabular organisms) to be more or less impossible without the posteriorly attached siphuncle; also that there may be a connexion between the attachment (in Ammonoidea) to the inflated beginning of the siphuncle or cæcum (itself attached by one or more bands, the so-called prosiphon) and the progression of the end of the protoconch (in phylogeny) from asellate and latisellate to angustisellate, as opposed to the reverse tendency of the following suture-lines to deepen the external lobe. But these suggestions will be difficult of demonstration.

In conclusion, I hope that since several siphuncular structures, notably "Grandjean's membrane", still remain unexplained, Dr. Trueman will continue his investigations into the Ammonite siphuncle. L. F. Spath.

[This letter was received just too late for insertion in the February number.—Ed. Geological Magazine.]

THE GENOTYPE OF *SPIRIFER*.

Sir,—By some regrettable mischance certain errors of reference occur in my communication to your Magazine, January, 1920, pp. 18–20. The following corrections are required :—

p. 19, line 5 from bottom, for "M.C. ii, pl. cclxiii" read "M.C. iii, pl. cclxv".

p. 20, line 5 from top, for "M.C. ii, pl. cxxv" read "M.C. ii, pl. cclxv".

p 20, line 8 from top, for "M.C. ii" read "M.C. iii".

p. 20, line 12 from top, for "141, 142" read "41, 42".

I may also take the opportunity to point out that Sowerby's plate of *Spirifer striatus* is numbered in M.C. iii, "170," whereas it is intended for "270". The text says "*Spirifer striatus*, Tab. cclxxi", whereas it should be "cclxx". His index corrects these errors.

I desire to thank my vigilant friend Mr. Tutcher for noting my lapses.

S. S. Buckman.

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EDITORIAL NOTES.

WE regret to announce the death of Professor Charles Lapworth, in his 78th year. Few geologists have exerted a more profound influence upon the progress of our science. His labours among the older rocks are a witness to his genius. He founded a Geological School of the first rank in the University of Birmingham, but the influence of his teaching was by no means confined to the students of that University. Many prominent geologists at home and abroad must be proud to regard themselves as his pupils. By his application of geology to various matters of economic importance he made it abundantly clear to men of business that this science was of great practical utility. His books are marked by high originality as regards both treatment and subject-matter. He was a man of singular charm, and greatly loved by all who knew him. A life of Professor Lapworth appeared in this Magazine in 1901 as one of our "Eminent Living Geologists". We hope shortly to give an appreciation of his life and work.

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OUR readers will doubtless notice the disappearance from this number of a familiar feature, namely the abstracts of papers read to the Geological Society of London. For the last few months, owing to a large influx of original papers, reviews, and correspondence, it has been difficult to afford the requisite space, and publication has often been considerably delayed. It may be taken for granted that the great majority of our readers receive these abstracts together with the discussions, which we do not reproduce, direct from the Society in due course. The abstracts have to be entirely reset in type, and it is considered that the cost of this would be better bestowed on original articles and on reviews. It is intended, however, to continue the publication of abstracts of papers read at the meetings of other societies of smaller membership, and even to enlarge this feature by the inclusion of brief summaries of papers of geological interest read to societies which are not purely geological in their scope, such as, for example, the Institution of Mining and Metallurgy. The Editors will be very glad to receive from Secretaries of local societies or from authors *short* abstracts of papers considered suitable for this section of the GEOLOGICAL MAGAZINE.

In the list of those recommended by the Council for election to the Royal Society we are glad to see the name of Dr. Robert Broom, of Griquatown, South Africa. The importance of Dr. Broom's work in anatomy and zoology is generally recognized, both in its bearings on the evolution of the higher vertebrates and in its relations to the study of South African stratigraphy. Dr. F. H. A. Marshall also, though pre-eminently a physiologist and agriculturalist, has taken much interest in the geological history of the vertebrates, and in particular of the domesticated animals, on which he has published some interesting details. But with these exceptions the list is, frankly, very disappointing. It does not contain the name of any geologist or of any representative of the allied sciences of mineralogy and geography. This is very discouraging to the workers in all these branches, now so numerous, and if this policy continues a deadlock will soon be reached, so that many eminent geologists, mineralogists, and geographers who have reached the meridian of life will see their chances of election indefinitely postponed, while for the younger generation the outlook is unpromising.

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Very different is the complexion of the similar list issued by the Royal Society of Edinburgh. This includes the names of no less than four geologists, namely Mr. E. M. Anderson, Mr. E. B. Bailey, Mr. R. G. Carruthers, all members of the Geological Survey of Great Britain, and Mr. W. R. Smellie, geologist on the staff of the Anglo-Persian Oil Company. Some of these gentlemen are valued contributors to our pages, and we are glad to avail ourselves of this opportunity to acknowledge with gratitude the support and encouragement that we have received from Scottish geologists, and especially from Mr. Bailey, during the recent crisis in the affairs of the Magazine.

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Captain W. B. R. King, O.B.E., M.A., F.G.S., of Jesus College, Cambridge, formerly of H.M. Geological Survey, and now Assistant to the Woodwardian Professor, has been elected to a Fellowship at Jesus College. We have already had occasion to refer more than once to the brilliant work carried out by Captain King as geologist on the Western Front, and we congratulate him heartily on this further distinction added by his college to his well-deserved honours.

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The Geological Society of London and the Mineralogical Society have set up a joint committee of twelve petrologists "to consider whether any standardization of British petrographic nomenclature is possible and desirable, and if so, to make recommendations with that end in view". The following six members were nominated by the Geological Society: Dr. J. S. Flett, Mr. A. Harker, Sir J. J. Harris Teall, Dr. H. H. Thomas, Mr. G. W. Tyrrell, and Professor

W. W. Watts. The nominations of the Mineralogical Society are as follows: Dr. J. W. Evans, Dr. F. H. Hatch, Dr. A. Holmes, Dr. G. T. Prior, Mr. R. H. Rastall, Mr. W. Campbell Smith. It is not yet known whether all the above nominees are willing to serve on the Committee. The first meeting of the Committee was held at 2.30 p.m. on March 16, when a preliminary discussion took place and certain resolutions were drawn up for consideration at the next meeting.

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We have been privileged to see a copy of a very interesting Report of a Commission appointed to examine the condition of the iron and steel works in Lorraine, in the occupied areas of Germany, in Belgium, and in France. Although the Report is in the main concerned with technical engineering details of the practice in the great iron and steel works of these areas, nevertheless there are to be found here and there items of information of geological interest, chiefly referring to the iron-ores of Lorraine and the coal of the Saar Basin. It is obvious that the terms of the Peace Treaty must have an enormous effect on the future of the iron and steel industries of both France and Germany. Before the War the iron-ore resources of France and Germany were estimated at 3,300,000,000 tons and 3,600,000,000 tons, or approximately equal. The relative positions at present are about 5,500,000,000 tons and 1,300,000,000 tons respectively. Thus France has now more than four times as much iron-ore as Germany, and it is expected that in the near future her annual production will rise to 42,000,000 tons, or double what it was before the War, and nearly three times as much as the British output. But at present the development of the industry is held up by the impossibility of obtaining from Germany the regular supply of Westphalian coal stipulated for in the Treaty. Saar coal alone is not satisfactory for blast-furnace coke, and requires an admixture of at least 25 per cent of Westphalian or British coking coal. The French ironmasters desire to establish a reciprocal trade with this country, exchanging Lorraine basic pig-iron for British coke, but the transport difficulty stands in the way. This may perhaps eventually be met by a system of canals. The scheme most favoured is that known as the "Canalization of the Moselle" from Thionville to Coblentz, with free navigation of the Rhine to Rotterdam, or canal from the Rhine to Antwerp. An alternative plan is for a canal from Dunkirk to the Briey ironfield. It is considered that this scheme would cause inconvenience in cutting through the thickly populated industrial districts of Northern France, and the cost would be enormous.

ORIGINAL ARTICLES.

The Pre-Glacial Valleys of Arran and Snowdon.[1]

By J. W. Gregory, F.R.S., University, Glasgow.

Contents.

Introduction.

THE history of the British Isles in the Pliocene has an important bearing on their glacial geology and on the origin of their existing geographical features. Physiographic evidence indicates that the Lower Pliocene was in Britain an epoch of depression, during which the sea covered parts of South-Eastern England, whereas the Middle and Upper Pliocene were marked by an uplift which excluded the sea from the British Isles, except in East Anglia and Western Cornwall. It is generally agreed that this uplift raised the low-lying plains that had been formed during the Lower Pliocene into plateaus from 500 to 1,400 feet above sea-level. The uplift lasted through a long period of time; and such a slowly rising land would naturally be greatly denuded by rivers. Plateaus and platforms due to the Pliocene uplift have been described by Dr. Mort for Arran and by Professor W. M. Davis for Snowdon; yet in their discussion of the present topography of those districts they attribute a very slight influence to stream erosion during the long pre-Glacial elevation.

The Island of Arran, amongst its many other attractions, offers much clear evidence on the history of this plateau and its bearing on the problem whether the Scottish valleys were made or merely moulded by glacial action. Dr. Mort has recently so attractively restated the case for the glacial origin of these valleys, that it may be advisable to summarize the evidence in favour of pre-Glacial rivers having been the more important agent in their formation. Though Dr. Mort's memoir appears to attribute to ice too large a share in the formation of the Arran valleys, it includes several such

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[1] Since this paper was written, shortly after a revisit to Snowdon in September, 1915, the Pliocene plateau of Carnarvon has been described by Mr. Dewey, who demonstrates the pre-Glacial age of the Snowdon valleys: "On the Origin of some Land-forms in Caernarvonshire, North Wales": Geol. Mag., 1918, pp. 145–57, Pl. VII. The publication of the present paper has been delayed by pre-occupation with other matters and two years' absence abroad; it is issued as originally written except for a few verbal changes. I am greatly indebted to Dr. A. Scott, who during my absence kindly re-drew the sections for press.

important additions to the geographical history of Arran as to form a contribution of permanent value to the literature of Scottish physiography.

1. The Valley System of North Arran.

North Arran has a comparatively simple structure in spite of the great variety of its rocks. It consists of a nearly circular block of granite (Fig. 1) which varies from 7 to 8 miles in diameter

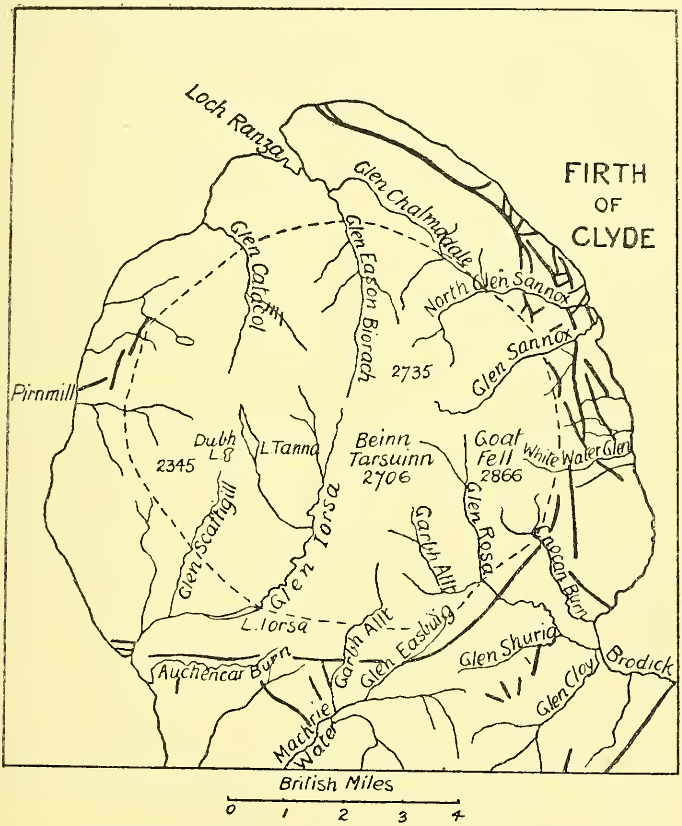

Fig. 1.—Sketch-map of North Arran, showing the faults (thick lines) and the granite (within the broken line).

and is surrounded by a girdle of metamorphic and sedimentary rocks. They formerly covered the granite as a dome from which rivers must have flowed radially in all directions. The highest mountain in Arran, Goatfell, is 2,866 feet, and three other summits rise over 2,600 feet; hence the area was apparently cut down to a plain at the height, in the granite district, of a little under 3,000 feet.[1] The date and mode of formation of that plain are uncertain; but it was probably cut when the country was lower than at present, and that plain may have been nearly at sea-level.

The history of the existing valleys begins with the elevation of this plain into a plateau. During the uplift radial streams must have flowed from the granite highlands. There are in North Arran about twenty-two radial streams in addition to the lower ends of the major valleys. These radial streams trend as follows:—

N.E. Two streams of North Glen Sannox.
E.N.E. Glen Sannox.
E. Four streams near Corrie, of which the longest is the White Water Glen.
S.E. Merkland Burn and Cnocan Burn from Goatfell.
S. The eastern Garbh Allt, from Ben Tarsuinn.
S.S.W. The western Garbh Allt from Beinn Nuis; and Auchencar Burn from S.S.W. of Beinn Tarsuinn.
S.W. Glen Scaftigill.
W. Eight burns, of which the longest is the Allt Gobhlach.
N.W. Abhainn Beag.

These radial streams are all of secondary importance. The major valleys, in which ground less than 1,000 feet in height reaches the centre of the granite mountains, run north and south. The granite dome is, in fact, dissected by three main valleys which cut across it north and south. The longest and most conspicuous of these valleys is that of Glen Iorsa and Glen Easan Biorach; it cuts across the middle of the granite mass. Further east is the valley of Glen Rosa, which is continued northward by Glen Sannox; this joint valley runs north and south for most of its length, but both its lower ends bend eastward to the sea. The third north and south valley, that of Glen Catacol and Glen Scaftigill, is on the western side of the island; its lower end bends westward to the sea, which the Scaftigill Burn reaches through the Iorsa Water. Each of these three valleys includes a large tract of ground below the level of 1,000 feet. On the floor of Glen Iorsa a band of alluvium, most of which is below the level of 250 feet, occurs in the very centre of North Arran; even the uppermost part of this alluvium is below 350 feet. Most of the floors of Glen Rosa and Glen Sannox are less than 500 feet above the sea.

In addition to the three north and south valleys there is another major valley in North Arran. It consists of Glen Chalmadale and North Glen Sannox; it crosses the island from Loch Ranza east-south-eastward to Sannox Bay and separates the plateau of Creag Ghlass Laggan (1,453 feet) from the rest of the highlands.

The valley system of North Arran may therefore be classified as follows:—

A. Minor Valleys.
    I. Radial valleys from the granite hills.
B. Major Valleys.
    II. The three north to south valleys across the granite hills.

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[1] This feature was recognized and illustrated by Sir A. C. Ramsay (1841, sect. i, opposite p. 8).

III. The north-west to south-east valley across the north-east of the island between Loch Ranza and Sannox Bay.

IV. The valley which crosses from Brodick over a divide at 768 feet and separates the mountains of North Arran from the moorlands that form most of the southern part of the island.

2. EVOLUTION OF THE EXISTING TOPOGRAPHY.

The most striking feature of the major valleys of North Arran is their independence alike of the main slopes and geological structure. The major valleys are not radial from the mountains and they are independent of the geological structure. Thus the three north and south valleys cut right across the granite mass, and though their lower ends bend seaward this change of course appears independent of the structure of the schistose and sedimentary girdle.[1]

However greatly the valleys may have been enlarged by denudation, their plan was determined by some influence which affected the area as a whole and was independent of its structure.

In order to determine the origin of these valleys and the extent to which they are due to glacial erosion it is necessary to determine the general topography of the country at the beginning of its glaciation. That topography was the result of the geographical evolution of the island after the igneous activity of the middle Kainozoic. The next process was the planing of Arran to a gently undulating tableland, of which the surface in the Goatfell Mountains was, perhaps, 2,000 feet above sea-level. The land extended further on all sides, and the slopes were longer and gentler than they are now. During this stage Arran was part of the mainland; and, as Dr. Mort suggests, the Chalmadale – North Sannox valley was probably initiated then by rivers that flowed south-eastward across North-Eastern Arran. The country was again uplifted, and Arran was isolated by tectonic valleys to east and west, and a series of north and south clefts parallel to these valleys cut across the granite mass of North Arran. The clefts were subsequently enlarged by denudation into the three major north and south valleys of the island.

After the second uplift the land must have remained stationary for a sufficient period, for the formation of a low plain, which was raised by a third movement into the thousand-foot platform (Fig. 2). This uplift doubtless reopened the north and south clefts,

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[1] Among the valuable contributions in Dr. Mort's paper is his rejection of the view that the difference in form between the central and western mountains was due to the texture of the granite. His objections to that explanation seem convincing. The western hills were completely overridden by ice, of which the lower part would have been charged with rock debris from the smooth central peaks and would have worn down the western summits into rounded ridges. The lower part of the snow-cap over Cir Mhor and Goatfell may have been converted to ice; but after the ice had removed the loose material it would have consisted of clean ice and have had but little abrasive power. By the time it had reached the western hills the lower layers were probably charged with rock fragments and were thus a more effective file.

and they were enlarged by denudation until their floors were but little above sea-level. During these movements the climate was becoming colder, as is shown by the disappearance from the British seas of those Lower Pliocene mollusca that are characteristic of warmer conditions. Frost action must have attacked the higher peaks and especially the slopes facing north and east; and the continual freezing and thawing of water in the joints of the granite led to the formation of corries along the margins of the snow-fields. Dr. Mort's memoir on Arran gives the first adequate description of its thousand-foot platform, which is also well developed in Ayrshire. Dr. Mort has advanced good reasons for the opinion that it was probably due in Arran to marine denudation.[1] If so, this platform is evidence of an uplift of at least 1,000 feet; and that it was several hundred feet greater than that amount is shown, as Dr. Mort remarks, by the buried valleys in South-Western Scotland. If this platform be a plain of marine denudation the uplift in Arran was not uniform. The platform varies in height from 800 to 1,200 feet around the Goatfell Mountains, and to the north-west of Brodick. It is from 700 to 1,000 feet beside the western coast from lower Glen Iorsa northwards to near Pirnmill; from 750 to 1,000 feet north of North Glen Sannox; from 500 to 750 feet in the south-western part of the island, between Blackwaterfoot and Glen Scorrodale; and between 500 or 600 feet and 900 feet in the south-eastern part of the island. That the uplift was differential agrees with the aspect of the land as seen from the steamer when approaching Brodick, as the platform slopes gently downward from the Goatfell Mountains both to south and north. That the greatest uplift occurred north of Brodick was recognized by Sir Andrew Ramsay (1841, section i, opposite p. 8), who represented the island as part of a great anticline with its axis ending on the eastern coast at North Sannox.

The uplift of the thousand-foot platform was unquestionably pre-Glacial, for deep valleys with glaciated floors, on which are well-preserved moraines, had been cut through it to the level of less than 100 feet above the sea. The effects of post-Glacial denudation on the island have been comparatively trivial; gorges, sometimes 30 feet deep, have been cut by streams through easily denuded rock. The post-Glacial period has been very short compared to that occupied by the formation of the major valleys.

In Glacial times Arran was a local glacial centre. Ice formed over the mountains of North Arran and flowed radially to the sea. Dr. Mort quotes with approval Gunn's remark that Arran had a "local icecap which shed material all round" (Gunn, 1903,

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[1] Professor Davis (1909, p. 289) gives as a criterion for the distinction of marine from subaerial plains that in sea-cut plains "the border of the unreduced masses should have been a sea-cliff"; while in subaerial plains "there would presumably be a gradual transition from unreduced masses to the reduced plain". As Dr. Mort points out, the abrupt ending of the platform against the mountains favours the marine origin of this plain.

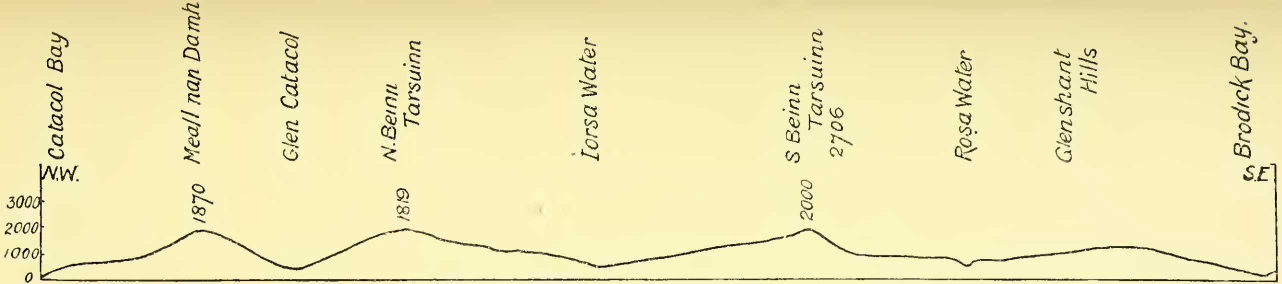

Fig 2. Horizontal scale ⅔" = 1 mile.

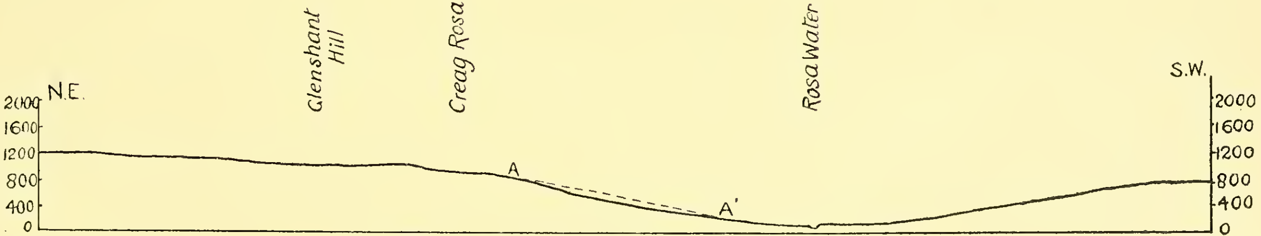

Fig. 3. Length of Section 1.5 Miles

FIG. 2.—Section from Catacol Bay, through Meall nan Damh, N. Beinn Tarsuinn, Glen Iorsa, S. Beinn Tarsuinn, to Glenshant Hills, showing the range of the 1,000 ft. platform in the S.E. part of the section. Horizontal scale, 1 inch = 1 mile.

FIG. 3.—Section across Glen Rosa through the 1,000–1,200 ft. platform on Glenshant Hill, and through the ice-worn slope of Creag Rosa to Glen Rosa.

On the view that Glen Rosa had its present depth in pre-Glacial times, the rock removed from Creag Rosa during the glaciation would be that between the broken line AA′ and the present surface.

pp. 132–3). "From the high ground of the interior," says Dr. Mort, "glaciers diverged, which finally joined the main streams, and moved south down the Firth" (Mort, 1914, p. 25). The flow to the north was blocked by ice from the mainland, and the chief discharge was southward. As granite erratics from Arran are rarely found in Ayrshire its ice must have been deflected to the south immediately after leaving the island by ice from the north.

If the Arran valleys had been formed by the radially flowing ice they should have been radial from the granite centre, and it has been claimed that they "run approximately from the centre in radial fashion" (Mort, 1914, p. 7). This is true of the minor valleys; but the most conspicuous feature in the arrangement of the major valleys of Arran is that they are not radial.

Dr. Mort remarks (op. cit., p. 71) that the Arran glens present features which cannot be explained by normal stream erosion; and this view is certainly correct as regards their plan, which would not have been adopted by streams flowing from the granite dome of Northern Arran unless the denudation had been guided by pre-existing lines of weakness. The same objection, however, would apply to ice erosion; for, unless guided by pre-Glacial valleys, glacial erosion should also have produced valleys radial from the high ground. The major valleys were probably determined by structural lines of weakness due to the uplift of the area. Glen Rosa and upper Glen Sannox occur along a basaltic dyke, which is the longest dyke in Arran. This dyke was forced into a north and south rift formed before the end of the igneous period. The uplift which formed the thousand-foot platform probably caused a series of north and south fractures which did not produce many faults, but rifts or bands of ruptured weakened rock (the shatter-belts of Marr). The streams naturally followed these rifts and weak bands, and thus the major valleys of North Arran were a series of three north and south valleys across the granite block. That these three valleys were tectonic in origin appears to be further indicated by their agreement with the general structural lines of the district. The general course of the eastern and western coasts has been determined by faults and fractures. Kilbrennan Sound to the west and the main Firth of Clyde to the east are probably both sunken blocks, which have been let down by north and south trough faults; and the block of North Arran was doubtless rent by north and south clefts formed by the same series of movements.

3. TECTONIC CLEFTS AND SHATTER-BELTS.

The valleys, however, are not fault valleys, as no recognizable displacement has taken place among them. They may be simple clefts formed by the gaping of fractures in rocks undergoing tension during uplift. The necessary formation of such tension clefts has been repeatedly asserted, as e.g. by James Smith in 1862 (p. 24), by Ruskin (1856, vol. iv, p. 229, i.e. pt. v, ch. xv, p. 31), and Bailey

Willis (1893, pl. lxxv). Such tension clefts would be narrow, but would be enlarged by the streams that would flow along them.

Broader valleys would be formed where tension is relieved by a multiple instead of by a simple fracture. This multiple fracture might consist of parallel fractures connected by cross fractures, or of anastomosing branching fractures. Such multiple fractures would produce a belt of shattered rock and thus form one variety of the shatter-belts of Professor Marr. His definition (1906, p. 77 ; reaffirmed 1916, p. 71) attributed shatter-belts to oscillatory faults, which cause no final displacement as the rocks on both sides are restored to their original positions by the backward and forward movement. He describes these belts as many yards in width and as composed of rock " broken into a rubbly mass of angular fragments of varying size in a matrix of finer crushed material ". Such belts of shattered material may also be formed by bands of rock being torn to pieces by tension cracks ; and some shatter-belts of the Lake District would appear to be more easily explained as multiple anastomosing tension clefts than as faults ; and the broader valleys of Arran and the major valleys of the rectilinear system around Snowdon may occur along shatter-belts due to tension during the Pliocene uplift. Shatter-belts probably often occur where they cannot be seen, for they would be seldom exposed on the floors of the valleys, and quickly obscured on the sides ; and in the absence of clear exposures, shatter-belts formed as crush breccias are indistinguishable from those due to multiple tension fractures. The term shatter-belt may be conveniently used for both kinds.

4. AMOUNT OF GLACIAL EXCAVATION IN THE VALLEYS.

With the increasing severity of the climate the country was occupied by glaciers, and they found an immature topography on which even limited glacial erosion would have produced conspicuous results. The ice flowing down the valleys must have pressed against the spurs, cut them back, and thus rendered the north and south valleys trough-shaped. There seems no convincing evidence that the ice materially deepened the valleys. Some of the alluvial plains may cover buried channels formed at the same time as those on the mainland ; but none of the freshwater lochs of Arran have floors lower than sea-level. No known Arran valley has been excavated below the base-level of the pre-Glacial rivers. Accordingly there is no need to assume the glacial deepening of the valleys.

The amount of hard rock removed by ice in widening the valleys was not necessarily considerable. The ice doubtless wore away the spurs, some of which are now represented only by blunt gables on the hill-sides, such as Torr Breac at the bend of Glen Rosa. The smooth spurless slopes at first give the impression of extensive ice erosion. But if, as seems most probable, the three north and south valleys were formed along tension clefts made by the uplift, their original course would have been straight and the spurs on their sides would have been short and blunt. Their pre-Glacial walls probably stood quite close to the existing walls. One of the best-known ice-worn slopes in Arran is the southern face of Creag Rosa. But a section across this slope based on the Ordnance maps (Fig. 3), even with the vertical scale magnified twice, does not give the impression of any great overdeepening. If the floor of the valley had been at its present depth in pre-Glacial times, the dotted line on the figure would indicate the approximate position of the pre-Glacial slope, The greatest thickness of rock removed by the ice would only have been about 100 feet, and this layer would have been weakened by pre-Glacial disintegration. The thickness of hard fresh rock removed would have been insignificant.

5. GARBH ALLT AND THE GLACIAL DEEPENING OF GLEN ROSA.

Dr. Mort, however, holds that Glen Rosa was glacially deepened to the extent of between 500 and 800 feet, a conclusion based mainly on the hanging valley of Garbh Allt. This stream rises on the south-eastern slopes of Beinn Tarsuinn, and at first flows south-south-east parallel to Glen Rosa; at 800 feet it bends suddenly eastward, and is joined by a tributary from the west; it follows the direction of this stream and discharges to the east-north-east by a series of cascades to Glen Rosa. It comes from a hanging valley which ends 500 feet above its confluence with the Rosa Water; and Dr. Mort holds that the difference in level between the hanging valley and the Rosa Water is due to glacial deepening of at least 500 feet and perhaps of 800 feet.

The limited corrosion by the lower Garbh Allt is capable of another explanation. Dr. A. Scott suggested to me the possibility that the Garbh Allt was originally the head of the Easbuig Burn (Bishop's Glen), a tributary of the Machrie Water; and a visit to the locality showed the high probability of the suggestion. Figs. 4 and 5 show five sections across the hills to the west of Glen Rosa. Section 4A crosses the upper part of the Garbh Allt, which there flows through a valley clearly separated from the parallel valley of Glen Rosa. Section 4B crosses the middle part of the Garbh Allt, where the eastern side of the valley is inconspicuous. Section 4C is along the lower course of the Garbh Allt below the right-angled bend at 800 feet; the section is continued westward along the tributary which continues the course of the cascades of the Garbh Allt. Section 5D is along the low flat rise which separates Garbh Allt from Glen Easbuig to the south-west, and from the tributaries of Glen Shurig to the south-east. Section 5E crosses Glen Easbuig from north-west to south-east at the same distance from D as that is from Section C and as C is from B. These sections show a continuous valley which was probably the original course of the Garbh Allt when, instead of turning to the east at C, it descended from 1,114 feet in B, over the depression at a little over 1,000 feet in Section D to Glen Easbuig. The Garbh Allt has now been diverted eastward to

Glen Rosa, along the junction between the schists and the granites. The character of the falls and their rock steps show that the lower end of the Garbh Allt is along a modern channel. The fact that the stream has not cut down its bed there more deeply is due to its recent adoption of its present course, and is not evidence of the glacial deepening of Glen Rosa.

Dr. Mort also claims (pp. 57–8) that Glen Iorsa opposite Loch Nuis has been glacially deepened by from 500 to 800 feet, since the stream from that loch has made no notch in the bank of Glen Iorsa ; but the loch lies on a projecting spur of the thousand-foot platform and the drainage from it is insignificant. The larger streams which join Glen Iorsa, as from Loch Tanna and the streams from both the Bens Tarsuinn, have deeply incised the sides of the main glen.

The position of Glen Diomhan as a hanging valley 200 feet above Glen Catacol is advanced by Dr. Mort (pp. 54–5) as evidence that the latter has been deepened by ice ; but as Glen Catacol is one of the tectonic north and south valleys it was probably older than its tributary ; and their difference in level is the natural consequence of the small Diomhan Burn not having been able to deepen its valley as quickly as the larger stream, which was working along a line prepared by a tectonic fracture.

6. ARRAN COMPARED WITH THE MAINLAND OF SCOTLAND AND SNOWDON.

The amount of erosion in Arran attributable to glaciers depends then on the view adopted as to the geographical condition of the island at the beginning of the Glacial period. This principle is applicable to other parts of the British Isles. If the glaciers had found Scotland in the condition of a worn-down country with a mature topography many of the existing features would indicate great denudation during Glacial times by ice, frost, and rivers. If on the other hand Scotland had then an immature and rugged topography the present features could have been produced with insignificant erosion. But as Scotland was uplifted before Glacial times at least 1,000 feet, the glaciers had to work on a country with many rugged youthful features, upon which comparatively slight rock abrasion would have produced a very marked effect. The Pliocene uplift also affected England. The movement was smallest in the south ; in North Wales it was as great as in Scotland, for it raised Snowdonia about 1,400 feet.[1]

The Snowdon area has many interesting analogies to Arran. Its major valleys are rectilinear, and they resemble those of Arran by their independence alike of the geological structure and natural lines of drainage. The main valleys of Snowdonia trend from north-west to south-east or from south-west to north-east. Where the

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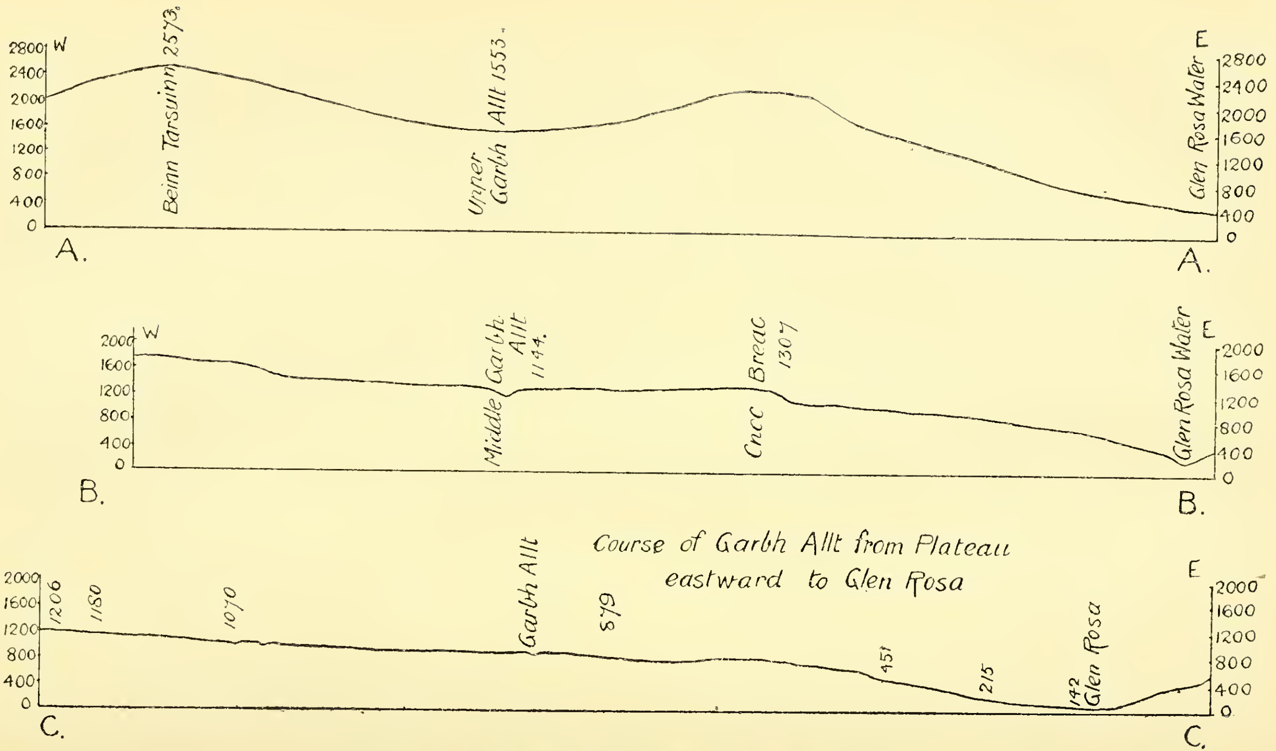
[1] In conversation with Professor O. T. Jones I was glad to find that he was also of the opinion that the Snowdon valleys had been largely made by pre-Glacial rivers eroding the uplifted plateau.



Course of Garbh Allt from Plateau eastward to Glen Rosa

Fig. 4.—Sections across the valley of the Garbh Allt, west of Glen Rosa. A. Section across the upper part of the Garbh Allt on the plateau west of Glen Rosa. B. Section across the middle part of the Garbh Allt before its bend eastward. C. Section along the western tributary of the Garbh Allt, and its eastward course to Glen Rosa.

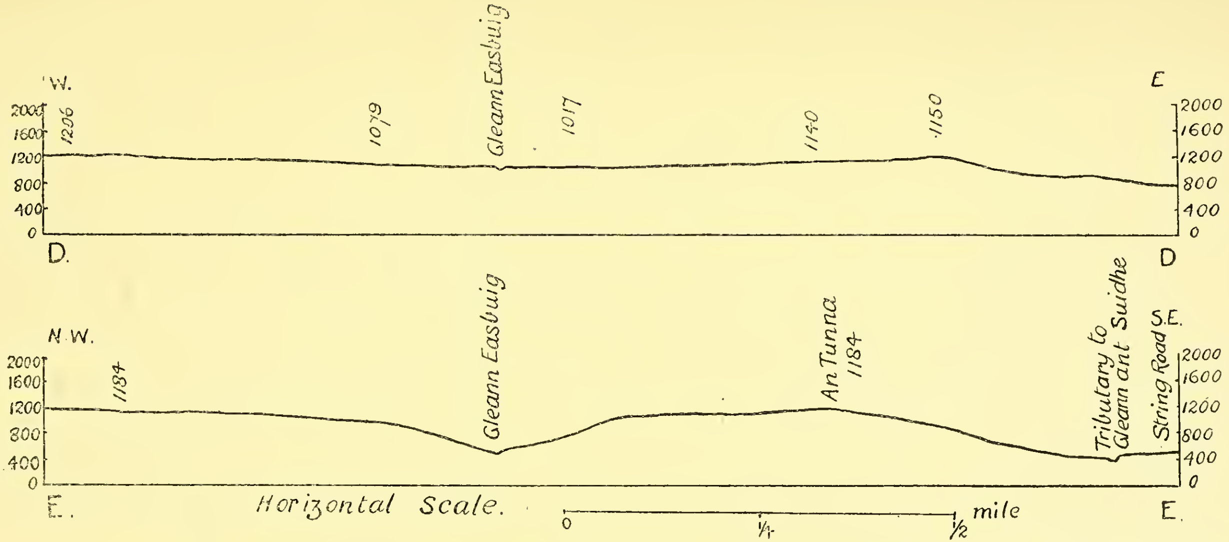


FIG. 5.—Sections across the valley of the Gleann Easbuig. D. Section along the divide between the Garbh Allt and the Gleann Easbuig. The main fall to Glen Rosa is further east. E. Section from N.W. to S.E. across upper Gleann Easbuig to the main valley traversed by the String Road.

valleys vary in direction they do so at sharp angles. Thus the Nant Gwynant runs north-eastward from Beddgelert to Penygwryd, where it bends east-north-east to Capel Curig; and on the continuation of its original direction occurs the valley of Llyn Cawlyd. The Nant Gwynant–Llyn Cawlyd valley is approximately parallel to the remarkably straight course of the 500 ft. contour along the north-western and western slopes of Snowdonia.

These rectilinear valleys have cut across some of the older valleys. Thus the formation of the Llyn Cwellyn valley beheaded the Afon Drws-y-coed (the upper part of the Nantlle valley) and captured its original head streams in the Cwm-y-Clogwyn, which, both from direction and gradient, appears the natural continuation of the Afon Drws-y-coed.

The course of this network of valleys is not what would be anticipated if they had been excavated by ice. If the valleys were glacial in origin they would have been expected to radiate from Snowdon, whereas the mountain is an oblong block enclosed in a rectilinear moat. The block would be almost an exact oblong but for the sharp bend in the south-western valley, which adds a triangular area to the southern corner.

A second resemblance to Arran is that Snowdon, as was clearly pointed out by Sir Andrew Ramsay (1881, pp. 271–3), was never completely overridden by extraneous ice. It was a centre of local glaciation; and as Ramsay remarked of its north-western glaciers (1881, p. 272), " on escaping from the high-bounding-walls of the upper parts of their valleys, they partly spread out in the shape of broad fans on the north-western slopes of the minor hills that now overlook the Straights." According to Ramsay, therefore, the valleys were pre-Glacial. The question is merely how far the glaciers enlarged and deepened these pre-existing valleys. The amount depends upon the condition of Snowdonia at the beginning of Glacial times; and, like the mountains of Arran, Snowdon was surrounded by a high platform trenched by pre-Glacial valleys.

Snowdon, at one part of the Pliocene, was apparently a mountain about 2,000 feet high surrounded by a low, widespread plain. The district was raised by a Pliocene uplift, and the plain formed the platform that now surrounds Snowdon at the height of from 1,250 to 1,400 feet. This platform occupies most of the area between the 1,250 and 1,500 ft. contours on the map (Fig. 6). It is shown in Ramsay's section through Yr Aran (1881, p. 158, fig. 23); the platform is at the level of from 1,200 to 1,400 feet to the north-west of Yr Aran, and somewhat lower to the south-east of it.

The uplift of Snowdonia led to the erosion of canyons along the floors of the old valleys, the width of which indicates that they had been worn down to base-level and their walls cut backward before the Glacial period. As the climate became more severe the gullies on the upper sides of these gorges were occupied by snow, and corries were excavated about them by the combined action of frost and streams.

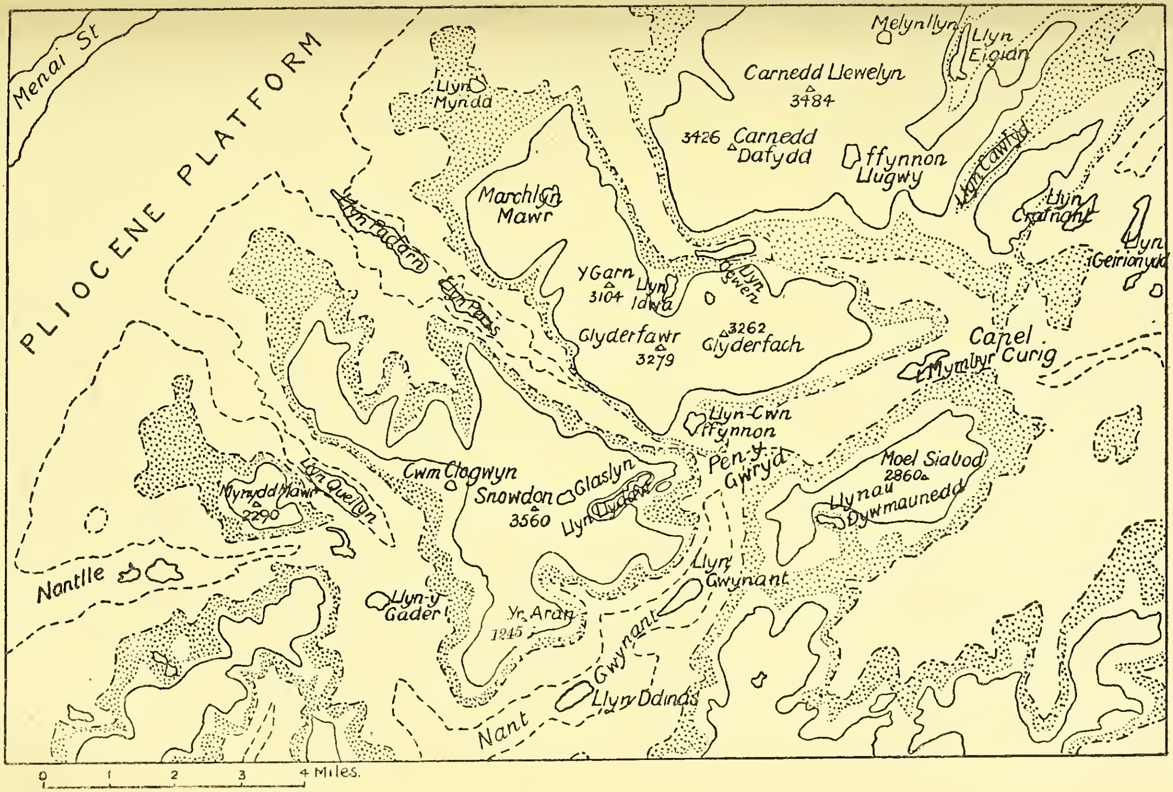


FIG. 6.—Sketch-map of the Snowdon district. The ground between the 1,000 ft. and 1,250 ft. contours is dotted to show the range of the upper platform.

When the glaciers flowed down the valleys they would have worn back the spurs, levelled the bars of rock on the floors, and thus the trough shape of the canyons, due originally to their formation along rectilinear fractures, was rendered more complete. The amount of solid rock removed by the ice according to this conception of the history of Snowdon was very small in comparison with that involved in the explanation adopted by Professor Davis. In his well-known paper both in the text and in an illuminating sketch (Davis, 1909, p. 307) he represents Snowdon at the beginning of the glaciation as a down-like upland, with gentle slopes and shallow valleys, cliffless, cragless, and without either corries or river gorges. In his paper (1909, p. 282) he describes pre-Glacial Snowdon as "a subdued mountain form with dome-like central summit, large rounded spurs, and smooth waste-covered slopes, and with mature valleys drained by steady-flowing streams". He maintained (ibid., p. 281) that Snowdon was altered during the Glacial period and chiefly by glacial erosion from "a large featured, round-shouldered, full-bodied mountain of pre-glacial time" "into the sharp featured, hollow chested, narrow spurred mountain of to-day".

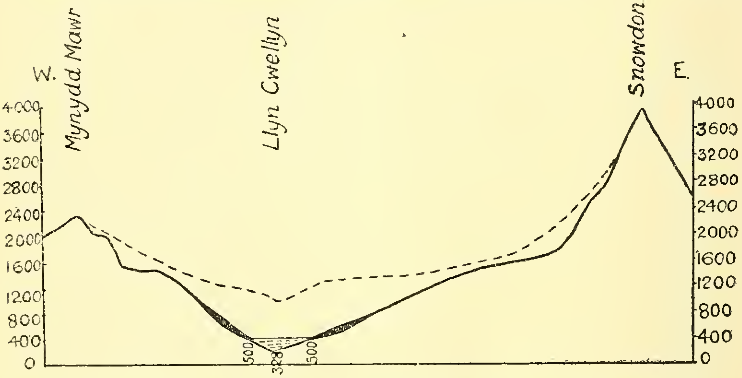


FIG. 7.—Section from Snowdon to Mynydd Mawr through Llyn Cwellyn. The broken line represents the approximate surface at the beginning of Glacial times, on the hypothesis that the down-like relief has been destroyed by glacial erosion. The areas in solid black represent the amount of solid rock removed on the alternative hypothesis that the valley had been excavated to approximately its present depth by pre-Glacial streams.

Professor Davis accepts the "late Tertiary" uplift of Snowdon, but considers that this would not have seriously changed its topography, as the only effect would have been the formation of a few minor gorges (p. 293). This conclusion is based on two arguments, first that Snowdon has no large trunk rivers, and the streams are not sufficiently different in volume to explain why some cut their valleys deeply and others were left as hanging valleys. These arguments would be conclusive if the valleys had been cut by normal consequent streams flowing down a uniform dome. But if the major valleys be regarded as a reticular system formed along fractures which gaped open at the uplift of the country, they could have been made without trunk rivers; and the depths of the main valleys as compared with some of their tributaries is a natural consequence of the more rapid denudation along the tectonic ruptures.

Professor Davis supports his case by reference to the rounded mountains, or "Moels". He holds (1909, p. 293) that they were not overridden by northern ice or "overwhelmed by the local ice", and that their rounded forms have been retained from pre-Glacial times; and he therefore claims that the adjacent valleys were also rounded then. But if the Moels on the north-west spurs of Snowdon have retained their pre-Glacial forms, they would tell against the view that the mountain has been greatly altered by glacial erosion, since some of them were in positions especially exposed to abrasion by the ice from central Snowdon.

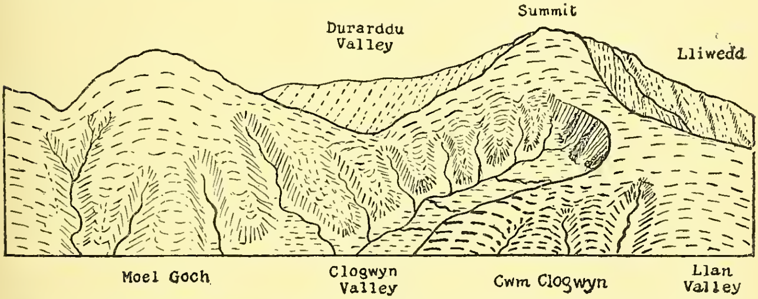


Fig. 8.—Hypothetical sketch of Snowdon from the north-west at the end of pre-Glacial times, illustrating the valleys formed in consequence of the Pliocene uplift.

As Snowdon stands in a position which rendered it subject to a heavy precipitation and is very varied in structure and composition, it appears improbable that it should have suffered so little from stream erosion during the long Pliocene uplift, as is admitted by Professor Davis' explanation. According to his view, on the section from Mynydd Mawr across Llyn Cwellyn to Snowdon, the pre-Glacial floor of the valley would have been at the present level of about 1,250 feet; Snowdon and Mynydd Mawr would have risen from the valley in gentle mature slopes along the upper boundary of the shaded area in Fig. 7. The valley below the broken line would have been excavated by glacial action.

According to the alternative view the pre-Glacial surface was along the lower line; the valley was a deep trench in the 1,200 to 1,400 ft. platform; the bed of the lake is 122 feet lower (Jehu, 1903, p. 436). The greatest removal of solid rock by the ice would have been along the edges of the Llyn Cwellyn Valley, and the amount removed would have been approximately that marked in solid black. According to this interpretation the topography of Snowdon at the beginning of the glaciation was essentially the same as it is now. Professor Davis's sketch probably shows the nature of the mountain slopes in the early Pliocene; but at the end of that period the increased power given to the streams by the uplift had enabled them to deepen their beds until they flowed through steep-walled gorges. The aspect of the mountain if seen from the north-west would probably have been approximately as represented in Fig. 8. The earlier down-like relief had been mostly destroyed owing to the excavation of the valleys of Snowdonia, like those of Arran, by streams during the Middle and Upper Pliocene uplift.

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Note on the Determination of the Limit between the Silurian and Devonian Systems.

By L. DUDLEY STAMP, M.Sc. (Lond.), A.K.C., F.G.S.

IN a recently published paper on the "Highest Silurian Rocks of the Clun Forest District, Shropshire",[1] the present writer gave an account of an area where the series of "passage-beds", marking a gradual transition from Silurian to Old Red Sandstone conditions, is well seen. The succession there is practically identical with that established by Miss Elles and Miss Slater in the Ludlow District.[2] From November, 1918, to October, 1919, whilst engaged in a study of Belgian Tertiary rocks, I have had an opportunity of visiting some of the more important sections of the Gedinnian in the Ardennes and also of examining the palæontological collections at Brussels, Lille, and elsewhere. This work has thrown very considerable

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[1] Quart. Journ. Geol. Soc., vol. lxxiv, 1918, p. 221, 1919.

[2] Ibid., vol. lxii, 1906, p. 195.

light on the English succession, and it seems desirable to give here a resumé of the conclusions reached.

I. NOTES ON THE SUCCESSION IN BELGIUM, NORTH FRANCE, AND ENGLAND.

A. The Ardennes.

The generalized section of the base of the Devonian in the Ardennes is as follows:—

Gedinnien supérieur . .	Schistes de Saint-Hubert. Schistes d'Oignies.
Gedinnien inférieur . .	Schistes de Mondrepuits. Arkose de Haybes and Arkose de Weismes. Poudingue de Fépin.

Well-marked unconformity.
Cambro-Silurian rocks, of which the most recent are of Wenlock and Lower Ludlow age.

The fauna of the Lower Gedinnian is not a large one, and has fortunately been reviewed in recent years by Professor Leriche in "La faune du Gedinnien inférieur de l'Ardenne".[1] The fauna there described comprises thirty-three species, excluding the Ostracoderms, described elsewhere by the same author.[2]

(*a*) *Gedoumont, near Malmedy, Belgian Prussia.*

Here the Lower Gedinnian, resting on Cambrian, is represented by a white sandstone (Grès de Gedoumont), which is perhaps the equivalent of part of the Schistes de Mondrepuits as well as the Arkose de Haybes. By far the most abundant fossils are *Chonetes striatella*, and a Rhynchonellid, identified by Leriche as *Rh. nucula.* It is a small form, apparently identical with the small form I have called *Rh. nucula* var., and noted as characteristic of the Upper *Chonetes* Flags in Shropshire.[3] It occurs also in the *Platyschisma* shales. The association of these two fossils is at once striking and suggestive to one who has studied the Upper *Chonetes* Flags of Shropshire. Occurring commonly also in the Grès de Gedoumont are *Orthis* cf. *lunata*, *Pterinæa retroflexa*, and corals (*Petraia bina* and *Cystiphyllum profundum*). The Devonian affinities of the fauna are seen especially in the occurrence of *Cryphæus* and numerous examples of *Spirifer Dumonti* (de Koninck). The latter may prove to be a derivative of *Sp. elevatus.*

(*b*) *Gileppe, near Verviers.*

Here the Gedinnian rests on Salmian rocks with *Dictyonema sociale.* The locality is to the north of the last (north of the "massif" of Stavelot), and the deposits are of the type generally referred to as Old Red Sandstone. They consist of rubbly green or red shales, with abundant cornstones, very closely resembling some

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[1] Mém. Musée royal d'Hist. nat. de Belgique, vol. vi, 1912.

[2] Mém. Soc. géol. du Nord, vol. v, 1906, pp. 26–39.

[3] Loc. cit., p. 231.

of the Temeside shales of Shropshire. The discovery of marine fossils in the latter has shown the folly of identifying this type of lithology exclusively with lacustrine conditions.

The Gedinnian has a similar facies to the south of Pepinster.

(*c*) *The Meuse Valley, south of Givet.*

Here some splendid sections show the Poudingue de Fépin—a thick, though local, conglomeratic base of the Arkose de Haybes—resting on the upturned and eroded beds of the Cambrian. The Arkose is succeeded by the Schistes de Mondrepuits (which are not here very fossiliferous) and then by the Upper Gedinnian.

(*d*) *Mondrepuits and Macquenoise.*

Here occur the most fossiliferous exposures of the Lower Gedinnian (Schistes de Mondrepuits). The most abundant fossil is *Rhynchonella nucula*, again the small form of the top of our *Chonetes* Beds. Other characteristic fossils include *Pterinæa retroflexa*, *Bellerophon trilobatus*, *Spirifer sulcatus*, and *Orthis personata* (Zeiler), the latter (well-known from the Coblentzian) indicating clearly the affinities of the fauna with the succeeding Devonian.

B. THE NORTH OF FRANCE (PAS-DE-CALAIS).

During the German occupation of Lille, Professor C. Barrois, Dr. P. Pruvost, and M. G. Dubois employed the leisure of their forced confinement in the city in studying a large series of specimens of Silurian and Devonian rocks from shafts and borings round Liévin, Lens, Béthune, etc. A complete series of transition rocks from the Silurian (Aymestry horizon) to the Devonian occurs in this region, thrust over the Pas-de-Calais Coalfield. Results of very great interest and importance have resulted from this study, of which, apart from previous descriptions of a small part of the fauna,[1] only a short resumé has yet been published.[2]

I am deeply indebted to Professor Barrois and Dr. Pruvost, who have allowed me to examine the specimens at the University of Lille.

The succession established is as follows :—

		Thickness in metres.
Gedinnien supérieur	Schistes et grès rouges et verts de Vimy	about 200
	Schistes et grès rouges et verts de Pernes	about 200
Gedinnien inférieur	Psammites de Liévin	about 80
	Schistes de Méricourt	23
	Arkose de Bois-Bernard	0–6
Gothlandien supérieur	Grauwacke de Drocourt	22
	Calcaire d'Angres	62
	Calcaire de Liévin	12

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[1] Gosselet, Barrois, Leriche, & Crépin, "Description de la Faune siluro-dévonienne de Liévin": Mém. Soc. géol. du Nord, vol. vi (ii), 1912. Leriche, Mém. Soc. géol. du Nord, vol. v, 1906.

[2] C.R. des Séances de l'Acad. des Sci. (Inst. de France), vol. 167, 1918, p. 705.

The Calcaire de Liévin has yielded six species, with *Dayia navicula* in great abundance.

The Calcaire d'Angres is a blue limestone, crinoidal at the base, with thirty-two species, including *Rhynchonella nucula* (large form identical with the characteristic form found in our *Rhynchonella* Beds), *Acaste Downingiœ*, *Calymene Blumenbachii*, and *Leptœna rhomboidalis*.

The Grauwacke de Drocourt has yielded sixty-three species, including *Spirifera elevata*, *Orthis lunata*, *O. canaliculata*, *Homalonotus* spp., *Pterinœa retroflexa*, and numerous Orthoceratids, including the "nodules à *Orthoceras*", so well seen in the *Rhynchonella* and *Chonetes* Beds of Shropshire.[1]

The Arkose de Bois-Bernard is a local bed of coarse sandstone at the base of the Schistes de Méricourt.

The Schistes à *Tentaculites* de Méricourt yield a very rich fauna of fifty-eight species, including *Retzia Bouchardi*, *Tentaculites irregularis*, *Pterinœa retroflexa*, and other lamellibranchs, *Cryphœus* spp., abundant *Primitia Jonesi*, *Orthis personata*. There can be no doubt of the identity of this bed with the Schistes de Mondrepuits.

The Psammites de Liévin have alternating beds with *Pteraspis Gosseleti* (Leriche), *Cyathaspis Barroisi* (Leriche), and typical marine beds with *Modiolopsis complanata* and *Orbiculoidea*.

The Schistes et grès de Pernes and the Schistes et grès de Vimy are only separable by their faunas, the former being characterized by *Pteraspis Crouchii*, *Pt. rostrata*, and *Cephalaspis Lyelli*; the latter by a rich and entirely different series of fish remains not yet described.

C. SHROPSHIRE.

It is not necessary to repeat here the well-known established sequence in Shropshire.[2]

The beds, which I have termed in the western area the *Platyschisma* shales, represent a deeper-water facies of the lower part of the Downton Castle Sandstone. The fossils mentioned on p. 233 of my paper as being survivals from the *Chonetes* Beds are perhaps more correctly regarded as the continuation of the normal fauna, whereas the fauna associated with *Platyschisma helicites* is a specialized shallow-water one. This point needs further investigation.

II. NOTE ON THE CORRELATION TABLE (p. 169).

This is practically identical with that already advocated by Barrois, Pruvost, and Dubois (op. cit.), who approached the subject from an entirely different standpoint—that of the study of the faunas in the North of France. My conclusion as to the relation of the

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[1] Stamp, loc. cit., pp. 228–9.

[2] Elles & Slater, Quart. Journ. Geol. Soc., vol. lxii, 1906, p. 195; Stamp, ibid., vol. lxxiv, 1918, p. 221, 1919.

Gedinnian of the Ardennes with the English Downtonian[1] was formed before seeing their paper, or knowing of the succession in North France, and it has been amply confirmed by the wonderful series there exhibited.

III. WHERE SHOULD THE BOUNDARY BETWEEN THE SILURIAN AND DEVONIAN SYSTEMS BE PLACED?

(1) Palæontological Evidence.

The Silurian and Devonian systems were originally described from their development in England, where there is nowhere a superposition of typical marine Devonian on typical marine Silurian. The later detailed classification of the Upper Silurian and "Downtonian" has been formed on the supposition that the upper limit of the Silurian coincided with a change of facies from marine to lacustrine—a truly unsatisfactory basis for international correlation.[2]

The palæontological affinities of the fauna of the Gedinnian are briefly noted above. Those geologists who have advocated the placing of the Gedinnian in the Silurian have undoubtedly been correct in recognizing the close connexion of Gedinnian and Downtonian.[3] The difficulties of correlation largely disappear when Downtonian is considered as Devonian, since the supposed Silurian character of the Gedinnian lamellibranch fauna cannot be considered as of great importance. Palæontologists are generally agreed as to the unsatisfactory nature of lamellibranchs as zonal forms, and in any case our Silurian species are very imperfectly known.

In North France the percentages of Silurian and Devonian species in each bed have been worked out, and on this basis the summit of the Silurian should be taken at the top of the Grauwacke de Drocourt.

In Britain it is necessary to rely principally on fish remains, which, with one or two exceptions, are first found in the Ludlow Bone-bed. The Downtonian and Lower Old Red Sandstone are united by several genera and even species of Ostracoderms.

(2) Stratigraphical Evidence.

The Silurian sea of Upper Ludlow times was of comparatively limited extent. In Lower Gedinnian times on the continent of Europe the sea spread over a vast tract of country in the Ardennes[4]—

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[1] Throughout this note the term "Downtonian" is used in its restricted sense, applying only to beds above the horizon of the Ludlow Bone-bed.

[2] See Evans, Geol. Mag., Vol. LVI, 1919, p. 549.

[3] Leriche, "Poissons fossiles du Nord de la France": Mém. Soc. géol. du Nord, vol. v, 1906, pp. 13–21.

[4] Compare South Devon and Cornwall, Green and Sherborn, Geol. Mag., 1913, p. 70.

TABLE OF CORRELATION.

	ARDENNES.	N.E. FRANCE (PAS-DE-CALAIS)	SHROPSHIRE.	SOUTH WALES[2] (AMMANFORD DISTRICT, ETC.).
UPPER GEDINNIAN .	Schistes de Saint-Hubert Schistes d'Oignies	Schistes et grès de Vimy Schistes et grès de Pernes	? [1]	Lower Old Red Sandstone Red Marls (part) with Green Basal beds.
LOWER GEDINNIAN .	Schistes de Mondrepuits Arkose de Haybes. Poudingue de Fépin.	Psammite de Liévin. Schistes de Méricourt. Arkose de Bois-Bernard.	Temeside Shales. Downton Castle Sandstone, including *Platyschisma* Shales. Ludlow Bone-bed at the base.	Tile stones. Trichrûg beds. *Grammysia* beds.
UPPER LUDLOW GROUP	Absent.	Grauwacke de Drocourt. Calcaire d'Angres.	*Chonetes* beds. *Rhynchonella* beds.	Upper Ludlow.
AYMESTRY GROUP .		Calcaire de Liévin.	*Dayia* Shales. Aymestry Limestone.	Aymestry Group.

[1] The lower part of the beds at present called Old Red Sandstone in Shropshire are probably equivalent to the "Red Downtonian" of Staffordshire (see King and Lewis, Proc. Birmingham Nat. Hist. and Phil. Soc., vol. xiv, 1917, p. 90). The latter beds yield *Scaphaspis truncatus*, *Eukeraspis*, etc., and must therefore be linked with the Temeside Shales as Downtonian and equivalent to the Schistes de Mondrepuits. True Lower Old Red Sandstone (*Pteraspis*, *Cephalaspis lyelli*) when defined in Shropshire would be placed here as equivalent to the Upper Gedinnian.

[2] The correlation of the beds in South Wales is a matter of considerable difficulty. Some localities exhibit a sequence comparable with that of Shropshire and show a complete and conformable series from Upper Ludlow to Lower Old Red Sandstone. (For example, east of the Ammanford area, see *Geol. Country around Ammanford*, Mem. Geol. Surv., 1907, p. 53; and on the Pembrokeshire coast, see *Geol. Country around Milford*, Mem. Geol. Surv., 1916, pp. 77, 97.) In South Wales there seems to be evidence of successive overstep, which is most pronounced at the base of the Red Marls (including their Green Basal Beds). The Red Marls are regarded as Lower Old Red Sandstone by the Survey on the evidence afforded by the discovery of *Eukeraspis* in the basal beds at one locality (see *Geol. Country around Newport*, Mem. Geol. Surv., 1909, p. 15), but this genus is characteristic of Downtonian rocks (including Downton Castle Sandstone) in Shropshire and North Staffordshire. It is true *Pteraspis* occurs in the upper part of the Red Marls, but it is possible, or even probable, that the lower part may be homotaxial with the Temeside Shales, with which there is a great lithological resemblance.

the greater part of the present Bassin de Dinant—and gave rise to well-marked basal conglomerates and sandstones (Poudingue de Fépin and Arkose de Haybes). The movement was isostatic in its nature, and was coincident with a shallowing of the pre-existing Upper Ludlow sea in North-East France. A very similar isostatic movement seems to be indicated in South Wales as noted on the correlation table. Thus in North-East France, Shropshire, and certain districts of South Wales, although there is a gradual transition from the Upper Ludlow to the shallower-water deposits of Downtonian age, the most widely spread disturbance, heralding the advent of the Devonian period, occurs in Lower Gedinnian and early Downtonian times. The commencement of this movement may possibly be indicated by the Ludlow Bone-bed.

In Scotland the Downtonian rocks[1] are sometimes seen to rest conformably on Upper Ludlow, with or without a conglomerate at the base; but an important transgression of the sea is indicated, for example, in Kincardineshire,[2] where Downtonian rocks, conformably overlain by Lower Old Red Sandstone, rest on ? Upper Cambrian. In the Southern Uplands there is sometimes a marked discordance (Pentland Hills and Ayrshire), and sometimes apparent conformity (Lanarkshire), between the Lower Old Red Sandstone and the Downtonian. The folding in the district is so intimately connected with the volcanic activity of Old Red Sandstone times, that the area must be considered in relation to others rather than by itself.

From the standpoint of physical geology, surely the only logical view is to regard the Downtonian as the commencement of the Devonian Period. To regard it as Silurian is to admit the enormous extension of the Silurian sea at the very end of the period, almost everywhere to be succeeded imperceptibly by Devonian or Old Red Sandstone, the rocks of the latter having, except in special cases, no natural stratigraphical base.

To this it may be objected that the Upper Gedinnian of North-East France and Belgium, as well as parts of the succeeding Coblentzian, are of "Old Red Sandstone" type, and are therefore to be regarded as marking the close of a period rather than as an integral part of the Devonian Period. Truly the rocks of this age in the Ardennes are not rich in fossils, and consist frequently of sandstones, indicating shallow-water conditions unfavourable to life. But lithology is by no means a sure indication of lacustrine or true Old Red Sandstone conditions. The discovery of marine fossils in the Downtonian of England—including the Temeside Shales of Clun Forest—in rocks which were regarded as typical of Old Red Sandstone, is paralleled in Belgium in the work of Dr. E. Asselbergs. This geologist, well

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[1] *Silurian Rocks, Scotland* (Mem. Geol. Surv.), 1899, pp. 68–9, p. 568 et seq.

[2] Campbell, "The Geology of South-Eastern Kincardineshire": Trans. Roy. Soc. Edin., vol. xlviii, 1913, p. 923.

known for his work on the Devonian, has traced fossiliferous marine bands in the Lower Coblentzian of the South of Belgium (Bassin d'Eifel),[1] and is of the opinion that the Old Red Sandstone (lacustrine) facies does not exist at all in the Ardennes. The existence of shallow-water and sparsely fossiliferous rocks in the Upper Gedinnian and Lower Coblentzian is only the natural consequence of the huge transgression and attendant shallowing of the sea in Lower Gedinnian times, and cannot be regarded as representing a change separating two periods—the Silurian and Devonian.

(3) CONSIDERATIONS OF PRIORITY.

Murchison originally drew the line of division between his Silurian and his Old Red Sandstone systems in Shropshire just above the Ludlow Bone-bed. It was only the occurrence of many of the Upper Ludlow fossils in the "Tilestones" (= Downton Castle Sandstone) that induced him to include the latter in the Silurian.[2] For reasons of priority it would be preferable to include the Bone-bed still in the Silurian, but there is evidence to show that bone-beds tend to occur at the base rather than at the summit of systems. The writer considers the Ludlow Bone-bed as an "organic" basal conglomerate marking the base of the Devonian system.

IV. CONCLUSION.

The absence of a clearly defined limit between the Silurian and Devonian in England has long been a great hindrance to workers both here and abroad. The result has been apparent in recent years in the so-called "Gedinnian problem", i.e. as to whether the Gedinnian is to be considered as Silurian or Devonian.[3] It is at least desirable that a statement of our present knowledge should be clearly outlined. After the publication of the detailed account of the succession in North-East France, and also of further work on the Downtonian fish faunas of England,[4] it is hoped that the whole subject will be treated more fully by Dr. Pierre Pruvost and myself.

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[1] Mém. de l'Inst. géol. de l'Univ. de Louvain, vol. i, 1913.

[2] *Siluria*, 4th ed., 1867, pp. 134–5.

[3] See De Dorlodot, Bull. Soc. belge Géol., vol. xxvi, 1912, Proc. verb. pp. 17–39, 62–5; Ann. Soc. géol. Belgique, vol. xxxix, 1912, pp. M 291–M 371. Mailleux, "Le texte explicatif du lévé géol. de la plan. de Couvin," 1912 (Serv. géol. Belgique): Bull. Soc. belge Géol., vol. xxvi, 1912, Proc. verb. p. 139. Fourmarier, Ann. Soc. géol. Belgique, vol. xxxix, 1912, p. 233. Leriche, Bull. Soc. belge Géol., vol. xxv, 1911, Proc. verb. p. 327.

[4] Indicated by King & Lewis, Proc. Birmingham Nat. Hist. and Phil. Soc., vol. xiv, 1917, p. 90.

Carboniferous Fossils from Siam.

By F. R. Cowper Reed, M.A., Sc.D., F.G.S.

(*Concluded from p. 120.*)

Athyris subtilita (Hall). (Pl. II, Fig. 10.)

ONE internal cast of the pedicle-valve of a species of *Athyris* seems indistinguishable from *A. subtilita* Hall[1] which occurs in the Carboniferous of Belgium,[2] and has recently been recorded from Eastern Yunnan.[3] The general shape and narrow median sulcus, the concentric sublamellose growth-ridges, and small, parallel dental plates, are well seen in our specimen.

Spirifer (*Reticularia*) cf. *lineatus* Martin.

The peculiar and characteristic ornamentation of *Sp. lineatus* is found on a fragment of a crushed valve in the collection. This well-known species occurs in the Culm of Hagen, according to Nebe,[4] as well as elsewhere.

Camarophoria sp. (Pl. II, Figs. 11, 12.)

There is the flattened impression and the cast of the left half of the valve of a small brachiopod, possessing characters which indicate its reference to the genus *Camarophoria*. The beak is not preserved, and it is doubtful if it is the brachial or pedicle valve with which we have to deal. The cardinal angles are rounded; there are 4–6 faint, low, rounded ribs on each side of a median weak sinus, which also bears two or three ribs, but the lateral portions of the shell are devoid of ribs, and simply show a few strong concentric growth-ridges. These external characters seem to suggest a comparison with *C. Dunkeri* (Roemer) as interpreted by Holzapfel.[5] Another, but uncrushed specimen (Pl. II, Fig. 12) consists of the internal cast of a pedicle-valve, 12·5 mm. long and 15 mm. wide, which shows the triangular spondylium.

Productus concentricus Sarres-Kayser. (Pl. II, Fig. 13.)

There is one brachial valve of a species of *Productus* which seems to correspond precisely with the form described and figured by Kayser[6] as *Pr. concentricus* Sarres, from the Rhenish Culm. Our specimen, which measures 9 mm. in width, shows the ornament and shape distinctly, and is fairly well preserved. Another less

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[1] Davidson, *Mon. Brit. Foss. Brach.*, vol. ii, pp. 18, 86, 217, pl. i, figs. 21–2; pl. xviii, figs. 8–10.

[2] De Koninck, *Faune Calc. Carb. Belg.*, vol. iv, pt. vi, p. 73, pl. xviii, figs. 1–4, 12–28.

[3] Mansuy, op. cit., vol. i, fasc. ii, pt. ii, 1912, p. 92, pl. xvii, fig. 2; p. 98, pl. xviii, fig. 6.

[4] Nebe, op. cit., p. 447, t. xiv, fig. 14.

[5] Holzapfel, op. cit., p. 65, t. vii, fig. 8.

[6] Kayser, *Jahrb. k. preuss. geol. Landesanst.*, 1882 (for 1881), p. 83, t. iii, figs. 3, 4.

perfect example agrees with Kayser's fig. 4 of the same species. Bather[1] has described and figured this species from the Lower Culm Measures of Devonshire, and it seems to be characteristic of the Lower Carboniferous.

Productus lævipunctatus Sarres. (Pl. II, Fig. 14.)

One small internal cast of a nearly complete but slightly distorted pedicle-valve, with the brachial-valve displaced but attached, appears to be indistinguishable from the shell figured by Kayser[2] as *Productus lævipunctatus* Sarres. Our specimen is not crushed, and the shape of the pedicle-valve and large incurved beak are well seen. The species occurs typically in the Culm of the Continent.

Productus cf. *plicatus* Sarres.

The impression of part of a brachial-valve of a species of *Productus* showing the ornamentation may be compared with *Pr. plicatus* Sarres,[3] which occurs in the Culm of the Continent, and probably also in the Lower Culm of Devonshire.[4]

Chonetes cf. *rectispina* Von Koenen. (Pl. II, Fig. 15.)

In one of the specimens of a small species of *Chonetes*, the cardinal spines are preserved, and there are four on each side of the beak, successively increasing in length outwards, and all are directed nearly at right angles to the hinge-line. The shell itself is semi-elliptical to semicircular, and the cardinal angles are rectangular. The surface is not well preserved, but seems to have been covered with close, fine, radiating lines. In its characters, so far as known, it resembles *Ch. perlata* (McCoy),[5] but more especially *Ch. rectispina* Von Koenen,[6] from the Culm of Germany and Barnstaple.[7] *Ch. pseudovariolata* Nikitin,[8] which is figured by Loczy[9] and Schellwien[10] from the Carboniferous of China, possesses the same general shape and ornament, but the cardinal spines are rather obliquely directed outwards. Our best specimen from Siam measures 6 mm. in length and 9·5 mm. in width.

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[1] Bather, Quart. Journ. Geol. Soc., vol. li, 1895, p. 650, pl. xxviii, figs. 9, 9*a*, 9*b*.

[2] Kayser, *Jahrb. preuss. geol. Landesanst.*, 1882 (for 1881), p. 80, t. iii, fig. 5.

[3] Kayser, ibid., p. 81, t. iii, figs. 1, 2; Leyh, *Zeitschr. deut. geol. Gesell.*, xlix, 1897, p. 540.

[4] Bather, Quart. Journ. Geol. Soc., vol. li, 1895, p. 649, pl. xxviii, figs. 10, 10*a*, 10*b*.

[5] McCoy, *Syn. Carb. Foss. Irel.*, 1844, p. 120, pl. xx, fig. 9.

[6] Von Koenen, *Neues Jahrb. f. Min. Geol.*, 1879, p. 327, t. vii, figs. 4*a*, 4*b*. Kayser, *Jahrb. k. preuss. geol. Landesanst.*, 1882 (for 1881), p. 78, t. iii, figs. 13, 14.

[7] Bather, Quart. Journ. Geol. Soc., vol. li, 1895, p. 650, pl. xxviii, figs. 12, 12*a*, 12*b*.

[8] Nikitin, Dép. Carb. Moscou, Mém. Com. Géol. Russ., vol. v, No. 5, 1890, p. 27, t. ii, figs. 1–4.

[9] Loczy, op. cit., p. 73, pl. iii, figs. 8–13.

[10] Schellwien, in Futterer's *Durch Asien*, Bd. iii, Lief. i, 1903, p. 142, t. i, figs. 5–8.

Chonetes aff. *buchiana* De Koninck. (Pl. II, Fig. 16.)

Another species of *Chonetes* is represented by the internal cast of a pedicle-valve and the interior view of the same valve. The ribs, which are comparatively few (about twenty to twenty-five in all), and coarse, are equally and widely spaced, and show faintly through the substance of the shell, and the two pairs of muscle-scars are distinct. The valve is gently convex, slightly flattened near the cardinal angles, which are rectangular, and the beak is small and inconspicuous. There are several small, short, cardinal spines along the hinge-line. The shell measures about 8 mm. in width and 5 mm. in length. The species is probably allied to, if not identical with, *Ch. buchiana* De Kon.[1]

Chonetes sp.

There is the cast and impression of the pedicle-valve of another small *Chonetes*, which is distinct from that above described. It is transversely subtriangular and fusiform in shape, with acutely pointed and somewhat produced lateral angles, and is widest along the hinge-line. The median portion of the valve is strongly convex, and rises rather suddenly from the depressed lateral portions. The cardinal angles are pointed at about 45 to 60 degrees; the beak is obtuse and small, and scarcely projects over the hinge-line. The surface of the valve is covered with rather coarse, though small, rounded riblets, about thirty-five to forty in number. The internal cast shows rather large and widely separated pustules arranged in radial lines, and there are traces of narrow elongated muscle-scars. There are indications of the bases of a few small cardinal spines along the hinge-line. Dimensions: width, 8·5 mm.; length, 4·5 mm. The shape of our shell recalls *Leptæna convoluta* Phill.[2] from the Devonian of Croyde Bay, which McCoy [3] records from the Carboniferous of Ireland. Loczy's *Chonetes Flemingi* var. *gobica*,[4] from the Carboniferous of China, may also be compared.

Proetus cf. *coddonensis* Woodward. (Pl. II, Fig. 17.)

Description.—Pygidium transversely semicircular. Axis strongly convex, broad, about one-third the width of the pygidium and three-fourths its length, composed of seven complete rings with narrow, lateral portions indistinctly marked off by weak longitudinal furrows; tip bluntly pointed. Pleural lobes somewhat flattened, with four distinct pleuræ on each side (and traces of a fifth), and a half-pleura on each front edge; pleuræ radiating, straight, extending nearly to the margin of pygidium, successively decreasing in strength and length posteriorly, with raised subangular surface bearing a fine median furrow; interpleural furrows well marked. Fine weak marginal furrow, indistinctly separating off a rounded border.

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[1] De Koninck, *Anim. Foss. Carb. Belg.*, 1842–51, p. 208, pl. xii, figs. 1*a*–1*c*.

[2] Phillips, *Palæont. Foss. Cornw. Dev.*, p. 57, pl. xxiv, fig. 96.

[3] McCoy, *Syn. Carb. Foss. Irel.*, p. 119.

[4] Loczy, op. cit., p. 77, t. iii, fig. 14, text-fig. 15.

Surface of pygidium very finely granulated. Dimensions: length, 5 mm.; width, 8·5 mm.

Remarks.—Two pygidia occur on opposite sides of the same piece of rock, one with the shell preserved and the other in the condition of a hollow impression. These were identified by Professor Hughes as *Proetus*. The very short pygidium and small number of segments of which it is composed seem to necessitate the reference of these specimens to this genus rather than to *Phillipsia* or *Griffithides*, and we may compare it with the Lower Culm species, *Proetus* sp. *a*[1] and *Pr. coddonensis* Woodw.[2] from North Devon. *Pr. postcarbonarius* Gemmellaro,[3] from the Sosio Limestone of Sicily, seems also to be allied to our form. It is undoubtedly distinct from the species *Proetus ellipticus* Mansuy,[4] from the Dinantian of Eastern Yunnan, which seems to be the only species of the genus previously recorded from the Carboniferous of South-Eastern Asia. The occurrence of this typically Devonian and Silurian genus in these Siamese beds is a token of their low stratigraphical position in the Carboniferous. Apart from the Devonshire species, the only Carboniferous representatives on the Continent are *Pr.* (*Dechenella*) *angustigenatus* Leyh, and *Pr.* (*D*) *hopensis* Leyh, from the Posidonienschiefer of the neighbourhood of Hof.[5]

Phillipsia aff. *silesiaca* Scupin. (Pl. II, Fig. 18.)

One small imperfect middle shield occurs in the collection, measuring between 3 and 4 mm. in length, but there is sufficient preserved to decide its reference to the genus *Phillipsia*, though the species cannot be determined. The glabella is semi-oval, somewhat elongated, widening slightly posteriorly, with nearly straight sides, and it consists principally of a large somewhat swollen median lobe overhanging the front end, with a pair of very short lateral, nearly horizontal furrows indenting its sides and marking off incompletely a pair of very small lateral lobes, which are bounded posteriorly by the deeper and stronger short oblique basal furrows not reaching the meso-occipital furrow. The basal lobes are small, swollen, subtubercular, and subtriangular, and they are widely separated from each other by about three times their width. The eye-lobes are long, narrow, and rounded, and are closely pressed against the sides of the glabella, reaching from a point about half its length to behind the basal lateral furrows. The fixed cheek behind them seems to be very small, but this part is not well preserved. Several species of this genus have been described from the Lower Culm near Hof[6] and from the Lower Carboniferous of Silesia, and ours especially

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[1] Woodward, Quart. Journ. Geol. Soc., vol. li, 1895, p. 648, pl. xxviii, figs. 7, 7*a*.

[2] Woodward, Geol. Mag., Dec. IV, Vol. IX, 1902, p. 483, Pl. XX, Figs. 5–11.

[3] Frech, *Leth. Geogn.* I, *Palæoz.*, Bd. ii, Lief. iv, 1902, p. 506, t. 596, fig. 5.

[4] Mansuy, op. cit., vol. i, fasc. ii, pt. ii, 1912, p. 85, pl. xvi, fig. 2.

[5] Leyh, *Zeitschr. deut. geol. Gesell.*, xlix, 1897, pp. 522, 524, t. xvii, figs. 1, 2.

[6] Ibid., pp. 526–7, t. xvii, figs. 3, 4.

resembles *Ph. silesiaca* Scupin.[1] One of Nebe's figures[2] of a glabella attributed to his species *Phillipsia westphalica*, which does not show any lateral furrows, also seems somewhat to resemble our specimen.

Cythere (?) sp.

A minute oval ostracod, measuring less than 2 mm. in length, and with rather pointed extremities, occurs in the collection, but is not sufficiently well preserved for a description, but it may be referred to the genus *Cythere*.

Cladochonus cf. *Michelini* (Edwards & Haime). (Pl. II, Fig. 19.)

Three narrow, elongated, tubular corallites, expanding slightly at their funnel-shaped mouths and connected in a longitudinal linear manner, with a slight alternate direction to the right and left, may be compared without hesitation to the *Cladochonus Michelini* Edw. & H., as figured by Kayser[3] from the Rhenish Culm. This species also occurs in the Coddon Hill Beds of Barnstaple.[4] It seems closely similar in mode of growth to *Cl. Schlüteri* Holzapfel,[5] from the Rhenish Devonian. In our specimen from Siam the total length of the corallites is about 30 mm., the successive corallites measuring respectively 11 mm., 13 mm., and + 9 mm.

LIST OF FOSSILS FROM KUAN LIN SOH.

Pronorites aff. *cyclolobus* (Phill.).
Prolecanites (?) sp.
Nomismoceras (?) sp.
Glyphioceras (?) sp.
Pleurotomaria (*Mourlonia*) aff. *conica* Phill.
Euomphalus cf. *subcircularis* Mansuy.
Helminthochiton cf. *priscus* (Münster).
Parallelodon aff. *corrugatus* (De Kon.).
Edmondia sp.
Allorisma (?) sp.
Protoschizodus (?) sp.
Posidonomya Becheri Bronn, var. *siamensis* nov.
,, cf. *radiata* Wh. Hind.
Pseudamusium cf. *prætenue* (Von Koenen).
Aviculopecten cf. *densistria* (Sandb.).
Actinopteria sp.
Athyris subtilita Hall.
Spirifer cf. *lineatus* Mart.
Camarophoria sp.
Productus concentricus Sarres-Kays.
,, *lævipunctatus* Sarres.
,, cf. *plicatus* Sarres.

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[1] Scupin, ibid., lii, 1900, p. 8, t. i, figs. 1–3.

[2] Nebe, op. cit., p. 474, t. xii, fig. 4.

[3] Kayser, *Jahrb. k. preuss. geol. Landesanst.*, 1882 (for 1881), p. 85, t. iii, fig. 19.

[4] Hinde & Fox, Quart. Journ. Geol. Soc., vol. li, 1895, p. 644, pl. xxviii, figs. 19, 19*a*.

[5] Holzapfel, *Abh. k. preuss. geol. Landesanst.*, N.F., Heft xvi, 1895, p. 305, t. xii, figs. 1, 2, 4, 5, 7

Chonetes cf. *rectispina* Von Koenen.
,, aff. *buchiana* De Kon.
,, sp.
Proetus cf. *coddonensis* Woodw.
Phillipsia aff. *silesiaca* Scupin.
Cythere (?) sp.
Cladochonus cf. *Michelini* (Edw. & Haime).
Crinoid stems.

Conclusions.

In 1913 Mr. J. B. Scrivenor[1] referred to the above described collection of Siamese fossils as probably belonging to his "Raub Series", which he regarded as of Carboniferous and Permo-Carboniferous age, and a specimen of the fine-grained fossiliferous shale, which I sent for his inspection in 1916, was pronounced as resembling "weathered decalcified shale" of this series. We are unfortunately without any knowledge of the field-relations of the Patalung rocks, but the occurrence of beds of Carboniferous age in other parts of South-Eastern Asia, the East Indies, and China is well established. Since Scrivenor (op. cit.) gave a list of references to most of the literature, the important work of MM. Mansuy and Deprat[2] has appeared on Annam, Tonkin, and Yunnan, while Fliegel's[3] memoir should also not be forgotten in addition to those by Schellwien and Loczy, which have been quoted in the foregoing papers. Högbom's[4] recent summary of the geology of Siam does not deal with the Patalung region, and no fauna of a similar type is mentioned as occurring elsewhere in the country. The whole facies of the fauna is undoubtedly that of the Culm, and several of the species seem to be identical or very closely comparable with species occurring in beds of this age on the Continent and in the south-west of England. A remarkable lithological similarity is noticeable between these Siamese beds and those of Coddon Hill, near Barnstaple,[5] and the state of preservation of the fossils is practically identical, though no radiolaria have been so far discovered in the former. The species of *Posidonomya*, moreover, is scarcely separable from the typical Culm form, *P. Becheri.*

It is not possible to detect any faunistic resemblance to the Permo-Carboniferous or Productus Limestones of India and other parts of Asia, and the whole palæontological evidence appears to point to a reference of the beds to an older set of deposits, and to prove the occurrence of Culm conditions and a Culm fauna in this part of Siam.

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[1] Scrivenor, Quart. Journ. Geol. Soc., vol. lxix, 1913, p. 352.

[2] Mansuy & Deprat, Mém. Serv. Géol. Indo-chine, vol. i, fasc. ii and iv, 1912; vol. ii, fasc. iii and iv, 1913.

[3] Fliegel, *Palæontographica*, Bd. xlviii, 1901, pp. 91–136, t. vi–viii.

[4] B. Högbom, Bull. Geol. Inst. Univ. Upsala, vol. xii, 1913–14, pp. 63–128, map, pl. i.

[5] G. J. Hinde & H. Fox, Quart. Journ. Geol. Soc., vol. li, 1895, pp. 609–68, pls. xxiii–xxviii.

PLATE II.

Fig.
1. *Pronorites* aff. *cyclolobus* (Phill.). × 1½.
2. *Pleurotomaria* (*Mourlonia*) aff. *conica* Phill. × 1½.
3. *Euomphalus* cf. *subcircularis* Mansuy. × 2.
4. *Helminthochiton* cf. *priscus* (Münst.). × 2.
5. *Parallelodon* aff. *corrugatus* De Kon. × 1½.
6. *Edmondia* sp. × 2.
7. *Posidonomya Becheri* Bronn, var. *siamensis* nov. × 1½.
8. *Pseudamusium* cf. *prætenue* (Von Koen.). × 1½.
9. *Aviculopecten* cf. *densistria* (Sandb.). × 2½.
10. *Athyris subtilita* Hall. × 1½.
11. *Camarophoria* sp. × 2.
12. Ditto. × 1½.
13. *Productus concentricus* Sarres-Kayser. × 3.
14. ,, *lævipunctatus* Sarres. × 3.
15. *Chonetes* cf. *rectispina* Von Koen. × 2.
16. ,, aff. *buchiana* De Kon. × 2½.
17. *Proetus* cf. *coddonensis* Woodw. × 3.
18. *Phillipsia* aff. *silesiaca* Scupin. × 5.
19. *Cladochonus* cf. *Michelini* Edw. & Haime. × 1½.

REVIEWS.

Block Mountains in New Zealand. By C. A. Cotton. Amer. Journ. Sci., vol. xliv, 1917, pp. 249–93.

THIS pamphlet deals more especially with the block mountains of Otago, a district in which the block features are unusually well preserved. The upland surfaces in Central and Eastern Otago have been described by both Park and Marshall as portions of a dislocated plain of erosion, termed a peneplain, the present relief being regarded as the work of erosion.

The writer's hypothesis, however, involves planation, sedimentation, and deformation, followed by a period of erosion, during which larger areas of the planed undermass have been re-exposed by stripping of the cover. It is quite possible that some of the eroded surface of the undermass has never been covered, and therefore forms a true peneplain; but, to the writer's mind, conclusive evidence as to the former wide extension of an overmass is afforded by the occasional preservation of small outliers of the cover on the upland plateaus; by wide distribution of the "sarsen stones" derived from the cemented quartz grit; and by the manner in which planed surfaces of the older rocks emerge from under brown coal strata as well as quartz grits with the same inclination.

Stress is laid on the fact that fault scarps form the boundaries of a number of blocks in Central Otago, and sufficient evidence of faulting is furnished by the attitude of the covering strata at the bases of the scarps. The conclusion arrived at is that the relief is very largely—almost entirely—due to recent differential movement of crust blocks.

H. V. S.


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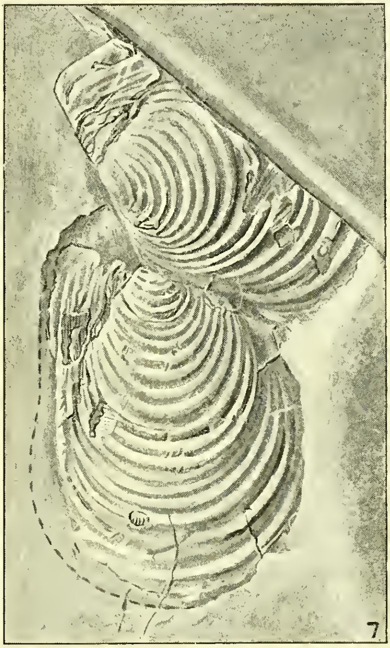
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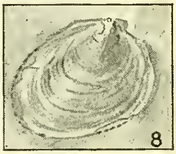
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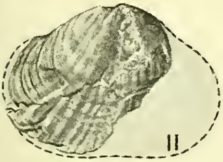
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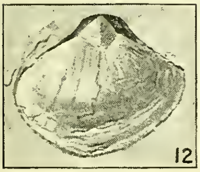
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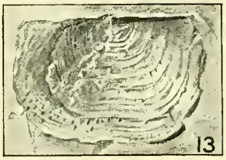
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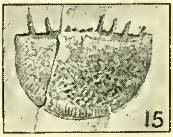
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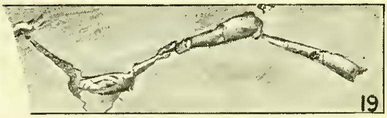
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CARBONIFEROUS FOSSILS FROM SIAM.

Tin Ores, 1919. Monographs on Mineral Resources. By G. M. Davies. pp. 111. Imperial Institute. 3*s.* 6*d.* net.

THIS monograph is one of a series which is being issued by the Mineral Resources Committee of the Imperial Institute. It is only in recent years that geologists have taken more than a passing interest in economic geology, but with the increased attention paid to it by eminent scientists the subject has assumed an academic importance not hitherto known, and one may recall the early days when it was treated as a mere accessory to mining instruction. The result is that the literature of mineral economics has improved, and this monograph is an excellent example of the way in which such a monograph should be prepared. It maintains a just balance of treatment between the statistical and scientific aspects, a feature often lacking in economic papers. On the whole this monograph is rather more economic than geological, and in this we discern that there is a difference between "mineral resources" and "economic geology".

Although the occurrences of tin ore in the British Empire receive the chief attention, the foreign statistics and geology are adequately dealt with, while the exports and imports of different countries give an excellent idea of the tin trade as a whole. Some of the information is of transient interest only and need hardly have been embodied, e.g. the price of metallic tin in London.

To English geologists the most interesting original contribution is that of Professor Cronshaw, who describes the structures of the Cornish and Devon lodes at various places, and we quote a passage relating to the lodes of Camborne. "The mineral contents show a definite arrangement within the lode fissures, and, moreover, display well-defined mutual relationships. This definite arrangement is the outcome of a definite order of intrusion, which, for the Camborne district—and it very probably admits of a wider application—has been found to be as follows :—

I. Large-grained and considerably brecciated quartz.

II. Small-grained quartz, cassiterite, tourmaline, and chlorite.

III. (*a*) Brown, finely crystallized tourmaline and chlorite, or 'brown peach' with minute grains of cassiterite and a certain amount of arsenopyrite.

(*b*) 'Blue peach' with cassiterite and some arsenopyrite.

IV. (*a*) Fluorspar, and to a less extent, secondary quartz veins containing a little copper pyrites and occasional recrystallized cassiterite.

(*b*) Calcite veins.

(*c*) Veins of hæmatite, iron pyrites, quartz, etc.

(*d*) Veins of galena, zinc-blende, quartz, and copper pyrites.

The bulk of the cassiterite made its appearance in stage III (*a*)."

It is interesting to note that Professor Cronshaw confirms the view of apparent connexion between the cassiterite and the lead ores, as a similar sequence of mineralization has frequently been noticed in other districts during the last decade. By early geologists this close genetic connexion was not credited, but its acceptance has led to the enunciation of theories which have yet to be developed on physico-chemical lines as a branch of the petrogenesis. There is no field of research which affords such scope for original work as the origin of lodes in their connexion with a consolidating magma, and particularly this question of the definite order of arrival of the minerals as an accessory function of it. As a whole the monograph is a complete treatise on the occurrence and production of tin ore as far as it is possible to make it in a few pages, and it is the best resumé of the subject yet published, the brief geological accounts being particularly good. D. A. MacAlister.

Marine Boring Animals Injurious to Submerged Structures. By W. T. Calman. British Museum (Natural History). Economic Series, No. 10. London, 1919. Price 1*s*.

THIS work, issued as a guide to an exhibit in the British Museum of the more important marine animals which are so destructive to timber and stone, will be of considerable interest to geologists.

Of the Molluscs which bore into wood a full and valuable account is given of the shipworm *Teredo navalis*, in which the boring is done by means of rows of fine sharp-pointed teeth on the front of the valves. Brief mention is made of other wood-boring lamellibranchs—*Pholas, Martesia, Xylophaga.* Next in importance to the shipworm as a destroyer of timber is the small Isopod Crustacean, known as the Gribble (*Limnoria lignorum*); other Crustacea which bore into wood are the Amphipod *Chelura terebrans* and the Isopod *Sphæroma terebrans.*

Animals which bore into rocks are more numerous than those which bore into wood, and include Sponges, Echinoderms, Worms, Molluscs, and Crustacea. *Pholas* is believed to make borings mainly by the rasping action of the shell which is provided with rows of spines or teeth towards the front edges. *Petricola pholadiformis*, although belonging to quite a different family (the Veneridæ), is remarkable for the close resemblance of its shell to *Pholas candida. Lithophaga* (*Lithodomus*) bores in calcareous rocks by chemical means, an acid secretion being formed by a gland in the mantle. *Saxicàva rugosa* is found mainly in limestones, and the boring is probably effected by chemical means. The principal Crustacean which bores into rocks is the Isopod *Sphæroma quoyana*, found on the coasts of Australia and New Zealand, where it burrows in soft sandstone and claystone. Other rock-boring animals described are the Polychæte worm *Polydora* and the Sponge *Cliona celata.*

In connexion with rock-boring organisms attention may be called to a recent paper by Professor T. J. Jehu, dealing with the subject from the point of view of coast erosion (*Scottish Geogr. Journ.*, xxxiv, January, 1918).

HANDBOOK OF MINERALOGY, BLOWPIPE ANALYSIS, AND GEOMETRICAL CRYSTALLOGRAPHY. By G. MONTAGUE BUTLER, E.M., Director Arizona Bureau of Mines. pp. vi + 311, iv + 80, viii + 155. New York: Wiley & Son. 1918.

THIS book is in reality three books bound in one volume, each part being separately paged and having its own title-page and index. It professes to be a notebook for use in the field, and for this purpose the first two parts, on the physical characteristics of minerals and blowpipe analysis, are very well adapted; the book is small, and will go into a not very large pocket; the printing is clear, and the descriptions are short and to the point. The only exceptions that may be taken are to the photographic illustrations, which are on too small a scale to show to any advantage, and to the determinative tables, whose use, in their present form, seems rather cumbrous. In the last section, on crystallography, however, too much reliance has been placed on descriptions unaccompanied by figures, with consequent loss of clarity; and in addition the use of Naumann symbols, to the entire exclusion of the Miller system, would appear to be a mistake, in view of the very wide use of the latter system.

W. H. W.

THE PHOSPHATE DEPOSITS OF SOUTH AUSTRALIA. By R. LOCKHART JACK. pp. 136. Bull. No. 7, Parts i and ii. Geol. Survey of South Australia, 1919.

SOME idea of the importance of the South Australian phosphate deposits may be gathered from the fact that in 1916 only 2,042 tons of crude mineral phosphate were produced, of which 1,652 tons were valued, after grinding, at £3 12*s.* 7*d.* a ton. The total amount of phosphate rock produced by the Colony up to the end of 1918 is given as 89,456 tons, valued at £89,456. In addition to calcium phosphate rock, "large bodies of phosphate of alumina exist at St. John's," near Adelaide, but the material is not acceptable to the manufacturers of superphosphate, and the State regards it as worthless. Part i gives accounts of the natural occurrence and methods of dressing the material and preparing it for the market, as well as its use on South Australian land. Part ii consists of 90 pages devoted to "Reports on Individual Deposits", and contains many plans of workings and prospects and a few plates from photographs.

The following notes on the geological occurrence are taken from the Bulletin.

Guano.—With the exception of three places on the mainland, where cave-guano occurs, deposits of guano are only found on the islands or coasts, but these appear to have been worked out. The bulk of the material contained from 25 to 42 per cent of calcium phosphate. According to a report by the late F. R. George in 1902 a considerable quantity of guano was removed from an island in Coffin's Bay, where it was mixed with sand, broken sea-shells, and vegetable matter, and in collecting this holes and cavities in the underlying limestones were followed down for the guano. At 10 feet phosphatic bone-breccias were encountered in the cavities.

Rock-phosphate.—The deposits of the mainland are found in association with metamorphosed Cambrian or pre-Cambrian limestones or in the adjacent argillaceous sediments. The author is in some doubt as to whether the phosphate with which the limestones are associated is a contemporaneous deposit, concentrated by the withdrawal of calcium carbonate in solution from phosphatic limestone, or whether the phosphate has been introduced from some extraneous source at a later date as a metasomatic replacement of the marmorized limestones and calcareous slate. "In their location among the steeply inclined sedimentary beds the bodies are generally close to the limestones . . . but others are found in clay-filled pockets in the strike of the limestone beds. Their position suggests derivation from the eroded portions of the limestones, and that precipitation of the phosphate by replacement took place either on the remaining limestone or in calcareous slate from which the bulk of the carbonate has been removed, the resulting rock being a phosphate with a high insoluble content. Metasomatic replacement is indicated by the presence of older veins of quartz, surrounded by phosphate . . . Another feature indicating metasomatism is the silicification of certain beds at some of the deposits to form a chert-like black to brownish-yellow rock containing a little phosphate," which is "frequently brecciated and contorted in places, and is found embedded in the phosphate rock. White to greenish sub-translucent, stalactitic, reniform, and mammillary phosphate is common, occurring as coatings of vughs, and wholly or partly surrounding masses of rock-phosphate, and is clearly secondary to the main mass of the rock in its order of deposition. Both limonite and manganese oxide are almost invariably associated with the phosphate rock. It is probable that in the replacement and solution of the rock containing the phosphate deposits, the iron set free has a tendency to segregate at the surface." This theory indicates subsequent replacement, and the author goes on to describe the close association of the deposits as a whole with Tertiary gravels which overlie the deposits. Where the latter have been eroded the deposits of phosphate do not exist. He associates the process of metasomatism with pre-Tertiary drainage, and the destruction of all the previously existing deposits not protected by the Tertiary gravels to post-Tertiary denudation. This implies that the deposits do not extend to great depth, but they have been proved to depths of 110 feet. He points out the absence of any evidence as to the true age of the phosphatization.

Apatite.—This occurs at Moonta, Wallaroo, and Balmacoota, in pegmatites of "pre-Cambrian age". In a vein near Balmacoota Spring the apatite makes up 40 per cent of two veins aggregating 5 feet in thickness.

The absence of proper petrographical examination detracts somewhat from the value of the Bulletin as a contribution to science, but no doubt it will prove of value to prospectors in South Australia.

PRELIMINARY REPORT ON THE GEOLOGY OF THE COUNTRY WEST OF SINOIA, LOMAGUNDI DISTRICT. By A. J. C. MOLYNEUX, F.G.S. Southern Rhodesia Geological Survey, Bulletin No. 6. pp. 47, with a folding sketch-map. Salisbury, 1919.

THIS memoir contains a preliminary account of the geology of an area in Northern Mashonaland, including the greater part of the "copper belt" of that region. It is interesting as revealing the existence of some 34,000 feet of stratified rocks, apparently unrepresented in Southern Rhodesia, but possibly correlative with the Transvaal or Potchefstroom System of the Union. The south-eastern portion of the area is occupied by crystalline schists, mainly of igneous origin, but including a belt of banded ironstone, probably sediments interbedded with the lavas. The gold-bearing rock, commonly known as the Eldorado conglomerate, is of uncertain origin, and the application of the term "banket" to it is deprecated, as it has no features in common with the Rand bankets. The overlying sedimentary rocks, which it is proposed to call the Lomagundi System, comprise fragmental and chemical deposits, including conglomerate, arkose, sandstone, shale, slate, limestone, and the Sinoia Cave dolomite group. The most important member is the uppermost or Piriwiri series, which attains a thickness of over 20,000 feet. The Piriwiri mineral belt, which is about 18 miles long and now worked to a considerable extent, carries gold and copper, the most important occurrence being the Eldorado mine, whose output to date has been about 432,000 ounces of gold.

R. H. R.

THE GENESIS OF THE ORES AT TONOPAH, NEVADA. By E. S. BASTIN and F. B. LANEY. U.S.G.S. Prof. Paper 104. pp. 50, with xvi plates and 22 text-figures. Washington, 1918.

THIS is an elaborate study illustrated by beautiful plates and figures of the genesis and relations of the ores of the well-known silver-producing mining area of Tonopah, Nevada. The author's conclusions, largely based on microscopic examination of polished sections, may be summarized as follows: the great bulk of the silver ores are of primary origin, but two types of primary minerals are recognized. The alpha-hypogene group have remained exactly as they were first deposited, including galena, blende, chalcopyrite, arsenopyrite, pyrargyrite, polybasite, argentite, wolframite, and electrum, with, probably, stephanite and argyrodite. The beta-hypogene minerals are those that have been formed by replacement of the alpha group during the primary mineralization, and comprise argentite, polybasite, chalcopyrite, and electrum. The minerals formed by oxidation and *supergene* enrichment are native gold and silver, argentite, polybasite, pyrargyrite, silver haloids, malachite, zinc silicate, with carbonates, quartz, chalcedony, barytes, gypsum, etc. An interesting feature is the evidence that has been found of the existence of one or more ancient periods of denudation and oxidation, at horizons now buried under subsequent deposits. The ore-veins are regarded as replacements of the volcanic country rock, now called the Mispah trachyte, and extending down into the underlying rhyolitic series, both being of Tertiary age. In many places the geological evidence is favourable to the persistence of rich primary silver ores to depths considerably greater than any yet reached, though hot ascending waters in the deeper workings may prove troublesome. It may be noted that the occurrence of such minerals as pyrargyrite, polybasite, and stephanite in a primary zone is unusual.

While not pretending to a high standard of culture in dead languages, the reviewer ventures to enter a vigorous protest against the employment of such a barbarism as the word "supergene", half Latin and half Greek. This is on a par with that journalistic horror, "hypersensitive." Surely Anglo-Saxon, or, at worst, good Latin terms can be found for such a simple idea as is here implied. What is the matter with "secondary"? R. H. R.

SUESS AS PALÆONTOLOGIST.

IN the number of the *Revue Critique de Paléozoologie* for January–April, 1919, which has just come to hand, M. G. F. Dollfus has an excellent article on the completion of the French edition of *Das Antlitz der Erde.* In it he discusses the palæontological work of Suess, and shows how it gradually led him on to those wider tectonic studies for which, indeed, it formed the evidence and the foundation.

It may be mentioned that the price of M. Cossmann's useful *Revue* has been raised to 12 francs per annum.

SOUTH AUSTRALIA DEPARTMENT OF MINES, MINING REVIEW NO. 30. pp. 56. Adelaide, 1919.

THIS report contains statistics concerning the mining industry of the State for the half-year ending June 30, 1919, and a number of special reports on points of interest. The most noteworthy feature of the period under review was the dislocation of the copper industry, leading to the cessation of smelting at Wallaroo, and almost complete stoppage of production. The development of resources of non-metals continues to progress, and reports are printed on deposits of barytes, whiting, graphite, and asbestos. The production of iron ore at Iron Knob has now reached the satisfactory figure of about 1,000 tons per day. The body of manganiferous iron ore is now exposed in two open workings to a depth of 100 feet, and the reserves are evidently very large. An interesting account is given of work carried out by the Wallaroo and Moonta Mining and Smelting Company, Ltd., for the welfare of their employees, which is of a most elaborate and well-organized nature, and conditions there appear to be ideal.

THE CLASSIFICATION OF THE PLAGIOCLASE-NEPHELINE GRANITOID ROCKS. By A. LACROIX. *Comptes Rendus*, t. 170, 1920, p. 20.

THE terms *essexite* and *theralite* have suffered somewhat from lack of definition and discrimination in their use. Rosenbusch suggested the term *theralite* for plagioclase-nepheline rocks of plutonic habit, and chose as the original type a rock from the Crazy Mountains, Montana, in which plagioclase was stated to be present. This was a mistake, as the rock proved to be a shonkinite, and recognizing this Rosenbusch afterwards took the unequivocal theralite of Duppau, Bohemia, as the type example. Lacroix, however, proposed in 1902 to use theralite for melanocratic alkali-syenites. He admits that with other petrologists he has applied the term inconsistently, and in an instructive paper he now attempts to put this group of rocks in order once and for all.

The term *theralite* he reserves for mesocratic rocks which differ from essexites in having a smaller proportion of potash-felspars (often reduced to a mantle bordering the plagioclase crystals), and in general a higher ratio of nepheline to felspars. In essexites, as in the type-rock of Salem Neck, there is a notable quantity of orthoclase or soda-orthoclase ; interstitial nepheline may be present, and hornblende is a constant ferromagnesian constituent.

From the theralites proper Lacroix separates two types in which the nepheline-felspar ratio is lower and the plagioclase more calcic than in the normal members of the group. *Luscladite*, one of these types, is characterized by the general absence of hornblende and the presence of olivine and often of biotite. The Crawfordjohn essexite is a British example, and Tyrrell's *kylite* is regarded as a melanocratic facies. The other type, *berondrite*, is characterized by the presence of elongated crystals of brown hornblende associated with titaniferous augite. The *montrealite* of Mont-Royal is a coarse-grained melanocratic variety. Theralitic rocks less rich in alkalies than those already mentioned are the *mareugites*, which are further characterized by hauyne, and which vary from highly felspathic to almost holomelanocratic types.

Two rocks are considered as heteromorphic forms of berondrite, since they differ essentially from the latter in mineral composition but not in chemical composition. In *mafraïte* nepheline fails to appear, its constituents being present in an aluminous soda-amphibole. In *fasinite* titaniferous augite contains the missing mineral, which in this case is plagioclase. Fasinite, though composed essentially of titaniferous augite and nepheline, thus differs from ijolite in containing abundant normative plagioclase. *Bekinkinite* is not dissimilar in chemical composition from fasinite except in its greater content of water. The minerals, however, are mainly hornblende and analcite.

Corresponding to the soda-series considered above, few leucite rocks are known, the granitoid types so far recognized being restricted to certain ejected blocks from the tuffs of Monte Somma. *Puglianite* is mainly composed of leucite, anorthite, and augite, and is the homologue of mareugite. A heteromorphic form of puglianite, known as *sebastianite*, is mainly composed of biotite, anorthite, and augite, and corresponds to mafraïte in the soda series.

The paper concludes with a series of thirty-three analyses, including several which appear for the first time.

Arthur Holmes.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

February 18, 1920.—Mr. E. B. Bailey, M.C., B.A., F.G.S., F.R.S.E., President, in the chair.

"On the Vascular Plants of the Chert Band of Rhynie, Aberdeenshire." By Dr. Kidston, LL.D., F.R.S., President of the Glasgow Geological Society.

The remains of four vascular plants have been discovered in the silicified peat bed at Rhynie, Aberdeenshire. These are—*Rhynia major* K. & L., *R. Gwynne-Vaughani* K. & L., *Hornea Lignieri* K. & L., and *Asteroxylon Mackiei* K. & L. Though their remains occur in more or less fragmentary condition, it has been possible, in the case of the first three, to obtain an almost complete knowledge of their morphology and anatomy. In regard to *Asteroxylon Mackiei* the vegetative region is known with considerable fullness, but the sporangia, which we believe to belong to this species, have not been found in organic connexion with its stem or branches, so there is an element of doubt on its fertile condition. All these vascular plants appear to have grown in a gregarious manner. A brief description of each may now be given.

Rhynia major was rootless and had no leaves. It consisted of a system of dichotomously branched cylindrical stems, which arose from underground branched rhizomes, that were attached to the peaty soil by numerous non-septate rhizoids. The plant was larger than *R. Gwynne-Vaughani*, and probably attained a height of 40–50 cm. There is, however, no clear information on this point.

The rhizome is composed of delicate tissue with a vascular bundle which dichotomized, and some of its branches grew upwards as tapering aerial stems. The stem bore no leaves or lateral projections. It consisted of a wide cortex composed of a narrow outer, and a wide, more delicate, inner zone. The vascular system consisted of a simple cylindrical stele, formed of a solid strand of tracheides, with no distinction of protoxylem and metaxylem. Surrounding the xylem was a broad zone of phloem.

The plant bore large cylindrical sporangia with thick walls, and contained numerous spores of one kind developed in tetrads.

Rhynia Gwynne-Vaughani was also rootless and leafless, and very similar in morphology and anatomy to *R. major*, but was a smaller species, probably not more than 20 cm. in height. It differed from *R. major* in having small hemispherical protuberances derived from the superficial tissues of the stem. These might remain as small protuberances, or develop rhizoids. Sometimes in place of the protuberances adventitious branches were produced, or bulbil-like growths attached by a narrow base that probably served for vegetative reproduction. The sporangia were of similar structure to those of *R. major*, but much smaller, and contained numerous spores of one kind.

Hornea Lignieri was a small rootless and leafless plant, whose stems branched dichotomously, and attained a diameter of 2 mm. They arose from a branched rhizome which had no vascular strand of its own. The stele of the stem consisted of a central cylinder of xylem, with smaller central and larger peripheral tracheides surrounded by a zone of phloem. The thickening on the tracheide walls is in the form of irregularly connected rings or a spiral. The stem has a well-defined cuticle and epidermis, but the cortical tissues are not clearly distinguishable into inner and outer zones. The cortex is usually very imperfectly preserved.

The sporangial cavity of the indehiscent sporangium is enclosed by a fairly thick wall, and had a sterile column of tissue or columella projecting so far from the base that the actual spore cavity is dome-shaped. The sporangia arose by the transformation of the tips of certain branches. The numerous spores are of one kind.

Asteroxylon Mackiei was a larger and more complex plant than any of the others. The stems arose from rhizomes without absorbent hairs. They attained a diameter of 5 mm. Some of the rhizome branches bent upwards and developed into leafy stems. The rhizomes have an epidermis with outer and inner cortex, and a cylindrical strand of xylem surrounded by a zone of phloem. The transition area between the rhizome and stem bears stomata and scale-leaves, and the xylem gradually assumes the stellate form of the stem xylem. The stem has a cuticle, epidermis with stomata, outer and inner cortex—the latter usually being separable into three zones—an outer, middle trabecular, and inner zone. The stele consists of a stellate strand of xylem enclosed in a zone of a phloem. The tracheides of both rhizome and stem have a prominent spiral thickening. The stem bears numerous simple leaves about 5 mm. long without any vascular bundle in the free portion, the leaf-trace stopping at the enlarged leaf-base. The free portion of the leaf is oval in transverse section.

The probable fertile region consisted of slender branched leafless axes and pearshaped sporangia about 1 mm. long, with regular apical dehiscence. Homosporous. Spores developed into tetrads.

MINERALOGICAL SOCIETY.

January 20, 1920.—Dr. A. E. H. Tutton, F.R.S., Past President, in the chair.

Dr. E. S. Simpson: "Gearksutite at Gingin, Western Australia." The mineral, which occurs in Cretaceous greensand, is considered to have a composition corresponding to the formula $CaF_2 . AlF(OH)_2 . H_2O$, and to have originated from the interaction in situ of fluorapatite, gibbsite, and carbonated water.—C. E. Barrs: "Fibroferrite from Cyprus." Analysis of material from Skouriotissa, Cyprus, gave the following result: Fe_2O_3 31·36, SO_3 30·95, H_2O (by difference) 37·01, insoluble 0·68.—Dr. G. T. Prior: "On the Classification of Meteorites." For purposes of the classification of meteorites the significance is pointed out of the chemical composition of the nickel-iron and the magnesium silicates. In the case of meteoric irons the structural features, as revealed by etching, are shown to be closely related to the content of nickel. In meteoric stones the proportion of magnesia to ferrous oxide in the magnesium silicates varies directly with the proportion of iron to nickel in the nickel-iron. On these principles the four classes of meteorites, viz. irons, stony-irons, chondrites, and achondrites, can be divided into interrelated groups. The three groups of chondrites are distinguished as enstatite-chondrites, bronzite-chondrites, and hypersthene-chondrites, according to the chemical composition of the pyroxene. The achondrites are divided into corresponding groups of enstatite-achondrites, bronzite (-augite) - achondrites, and hypersthene-achondrites, while a fourth group is added richer in lime (and mostly also in alumina) than the chondrites. To avoid confusion owing to Brezina's misuse of the term chladnite, the enstatite-achondrites, comprising Aubres, Bustee, and Bishopville, are called Aubrites, while for the hypersthene-achondrites (Shalka, etc.) a reversion is made to Tschermak's original name of diogenite.—A. F. Hallimond: "On Torbernite." In continuation of the author's previous work a series of weighings were made on Gunnislake material held over various concentrations of sulphuric acid. Dehydration did not occur at the pressure required, and only took place slowly over strong acid in a period of many months. It is clear that this mineral cannot be identical with ordinary torbernite. The refractive index agrees with that found for an abnormal torbernite by N. L. Bowen. Normal torbernite has the density 3·22 and mean index 1·585, while for artificial metatorbernite and for the Gunnislake mineral the density is 3·68 and the index 1·624. An approximate reading yielded for Gunnislake crystals $c : a = 2{\cdot}28 : 1$. The basal planes of the two forms are of the same dimension and the volume change due to the addition of $4H_2O$ is borne by an increase in the vertical axis. The density of the water of crystallization is 1·2, a value common in hydrated salts, while the refractive power is equal to that for liquid water.

Geologists' Association.

January 2, 1920.

"The Liassic Rocks of the Cardiff District." By A. E. Trueman, D.Sc., F.G.S.

The greater part of South Glamorganshire, from Cardiff westwards to beyond Bridgend, consists of Lower Liassic rocks (Hettangian and Lower Sinemurian), which are well seen in some 20 miles of magnificent cliff sections. Only meagre descriptions of these rocks have been hitherto published. A detailed study has been undertaken, first because nowhere else in this country are such continuous sections of these rocks available, and secondly because the normal deposits consisting of limestones and shales seen near Cardiff, when traced westwards, pass into littoral facies or massive limestones and conglomerates. In the present communication an account of the normal Liassic rocks of the Cardiff district is given, as this will form a basis for the correlation of the modified deposits further west.

The Liassic rocks near Cardiff occur in several outliers, the chief being those at Penarth, Lavernock, Leckwith, and St. Fagans; the sequence in the two former is clearly seen in cliff sections, and in those localities there exists an almost complete transition from Keuper to Lower Lias, so that they have become classical localities for the study of the Rhætic beds. In the cliffs at Lavernock, where the Liassic sequence has been most fully examined, the rocks are seen to form a gentle syncline, and since many of the limestone bands form extensive reefs on the beach it is an easy matter to collect fossils in place.

The general sequence at Lavernock and in the neighbouring outliers is as follows:—

		Feet.
Nodular limestones and shales, mainly *angulatus* zone,	about	40
Lavernock Shales, *angulatus* zone, with *Waehneroceras* in the lower portion	,,	40
Nodular limestones and shales with *Caloceras* cf. *Johnstoni*	,,	18
Limestones and shales with *Psiloceras* cf. *planorbe* .	,,	5
Limestones and shales (*Ostrea* beds)	,,	21
White Lias	,,	9

Liverpool Geological Society.

February 10, 1920.—Mr. W. T. Walker, B.Sc., F.G.S., President, in the chair.

The following paper was read: "Dumb-bell Islands and Peninsulas on the Coast of South China." By Walter Schofield, M.A.

The paper records observations made during a residence of several years in Hong-Kong, in the neighbourhood of which the "dumb-bell" island and peninsula—a physical feature of the coast of South China which attracts attention by its frequency—are especially common.

A "dumb-bell" may be defined as two land areas connected by a relatively narrow isthmus of sand which is never below high-water mark in any part of its length. The size of the areas of land may vary to any extent, but the highest points in both must rise higher above sea-level than any part of the isthmus. The best example is that known to English residents in Hong-Kong as Dumb-bell Island, which consists of two granite hills, each about 300 feet high and 1¼ miles long, connected by a low sandy isthmus 170 yards wide, rising 10 feet above normal high-water mark. The Portuguese colony of Macao is, perhaps, the most typical example of a dumb-bell peninsula.

There are several varieties of dumb-bell islands, and their origin is ascribed by Mr. Schofield to (1) decay of rocks, (2) partial submergence of the land, (3) rainstorms, (4) destruction of vegetation, (5) marine action, and these causes are examined and explained in detail. Nearly all the dumb-bell islands and peninsulas are composed of granite, generally partly decayed, and their evolution can be followed through all its stages in the examples near Hong-Kong. The paper concludes with a list of the islands and peninsulas of this type near Hong-Kong, to the number of forty-six.

CORRESPONDENCE.

THE SGÙRR OF EIGG.

Sir,—I have no wish to enter into a controversy upon the subject of the Sgùrr of Eigg with Dr. Harker, whose letter, I may be pardoned for suggesting, savours rather more of the "Don" than of the "Survey man". I may remark, however, that I have read Dr. Harker's paper carefully, and did not find it convincing. The occurrence of granite pebbles in the conglomerate may not be new now; I believe it was new when Mr. A. S. Reid and I made the discovery—in 1898. I have never seen any of the older granite fragments that Dr. Harker mentions, the granites "that are not exposed at the surface"; possibly they may be of Old Red Sandstone age. The granite pebbles we discovered in the conglomerate are certainly not of Old Red Sandstone age. In any case, this point concerning granite pebbles is arguable, but is not vital.

The question at issue between Dr. Harker and myself is something much more important, namely, the relative values of theoretical and field evidence. I bow to Dr. Harker's knowledge of microscopic petrology, but in matters of field evidence each man must rely on his own observation. It is possible to argue at any length about possibilities, probabilities, and theoretical matters, but there should be no possible mistake about facts as observed in the field. I cordially agree with Dr. Harker that a little knowledge is dangerous, but, on the other hand, assurance as to facts is very safe. Anyone who has a lengthy experience of economic geology—the kind of geological work that is practically useful, as distinguished from that which is more purely academic—will realize that absolute assurance as to facts in field evidence is essential. Less than absolute assurance may be interesting but is economically useless.

Dr. Harker and I, from our respective experiences in various parts of the world, obviously take different points of view, and therefore I suppose must agree to differ upon this problem of the Sgùrr of Eigg.

E. H. CUNNINGHAM-CRAIG.

THE DUTCH HOUSE, BEACONSFIELD.
March 1, 1920.

[The foregoing letter was submitted to Dr. Harker in MS.; his reply is printed below.—ED. GEOL. MAG.]

SIR,—I am sorry if the tone of my former note on this subject was unsuitable. It is no doubt a Don's failing to dislike being patronized, even by an old student.

I should not trouble you again were it not that Mr. Cunningham-Craig persists in representing that I stand for " theory " while he is the champion of " field evidence ". I must point out once more that my theory was the same as his until I came to survey the ground, when the field evidence compelled me to a different interpretation. There was no question of " microscopic petrology " until Mr. Craig introduced it, when he claimed to decide that the granite fragments in the Eigg agglomerate are of a Tertiary, not a Palæozoic type. It seems that, despite his compliments, he will not allow me the same privilege in respect of the granite fragments in Skye and elsewhere. His experience in many parts of the world may be, like Sam Weller's knowledge of London, extensive and peculiar, but does not seem to have much bearing upon this specific point.

ALFRED HARKER.

PALÆONTOLOGICAL ABSTRACTS.

SIR,—Probably most of your readers are by this time aware that the Société Géologique de Belgique has undertaken to publish a " Review of Geology and Connected Sciences ", consisting of summaries of recent papers written, so far as possible, by the authors themselves. Further information may be obtained from the Secretary to the Review, Laboratoire de Géologie, Université de Liége.

The object of this letter is to inform British Palæontologists that the new Review, instead of competing with *La Revue critique de Paléozoologie,* which M. Cossmann has been bravely conducting for over twenty years, will take it into collaboration, leaving the direction in the hands of M. Cossmann. All writers on Palæozoology in this country are therefore asked to be good enough to send M. Maurice Cossmann, 110 Faubourg Poissonière, Paris, Xe., separate copies of their papers, or if that be impossible, at least the title and bibliographic details of each publication.

F. A. BATHER.

THE CHINES AND CLIFFS OF BOURNEMOUTH.

Sir,—I believe that Mr. Bury is correct in assuming that I am responsible for the statement regarding the general increase in the steepness of the Bournemouth cliffs. It was made in a lecture on "The Bournemouth Cliffs" delivered at Bournemouth in the spring of 1912. The matter was also discussed at the Geological Society after the reading of Mr. Bury's paper on January 27, 1916.

As I have not visited Bournemouth since 1912 I am unable to refer to the appearance of the cliffs at the present time, but in 1912 the alteration in the general angle of face-slope was unmistakable, and, in fact, was noticed by several local observers, and subsequently corroborated by the comparison of numerous photographs taken between 1887, when my systematic observations began, and 1912.

Since the Undercliff Drive was constructed there has been a general lowering of the beach westwards, and hence a more rapid removal of cliff talus from the base through marine erosion and transport, while, at the same time, there has been no proportionate increase in the rate of atmospheric erosion upon the cliff-face. Hence the general angle of slope is no longer approximately 35 degrees, as was formerly the case. I predicted these changes when giving evidence at the Local Government Board Inquiry held at Bournemouth in 1906, and many years before that in the local papers.

It has always seemed to me that an important factor in determining the width and depth of a chine in the making is the bed of clay, or ferruginous sandstone, so frequently present at varying depths below the surface. A stream cutting its way through the softer sandrock ceases to erode its bed with the same rapidity when reaching a stratum of clay or sandstone below, while the widening of the chine by atmospheric agencies continues to progress at the same rate.

C. Carus-Wilson.

February 12, 1920.

INCOME-TAX.

Sir,—A committee has been formed to support the claim that expenses necessarily incurred by scientific men should be allowed as a charge against income in arriving at their assessment for income-tax. This is at present by no means always the case where the income is a fixed salary from a Government Department or Public Institution. As the whole question of the mode of imposition is now under revision, it is proposed to present a memorial to the Treasury on the subject, and it is hoped that it will be supported as widely as possible.

All communications on the subject should be addressed to Major A. G. Church, D.S.O., M.C., B.Sc., Secretary of the National Union of Scientific Workers, 19 Tothill Street, Westminster.

John W. Evans

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HENRY WOODWARD, LL.D., F.R.S.
AND
R. H. RASTALL, M.A.

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THE
GEOLOGICAL MAGAZINE

VOLUME LVII.

No. V.—MAY, 1920.

EDITORIAL NOTES.

THIS month our Editorial notes are shorter than usual, owing to pressure of other matter on our space, especially somewhat lengthy correspondence, which has to some extent upset the original programme and caused one or two papers to be unavoidably held over. Furthermore, the incidence of the Easter holidays has made it difficult to keep up with current events in the geological world.

* * * * *

IN the long list of recipients of various grades of the Order of the British Empire we are glad to notice the names of some geologists, though few in number. They are as follows: Mrs. Shakespear, Dame B.E.; Dr. F. H. Hatch, O.B.E.; Mr. J. Allen Howe, O.B.E.; Miss G. L. Elles, M.B.E.; Mr. H. T. Burls, M.B.E. We are by no means sure whether the first item on this list is correctly expressed; if not, we offer apologies.

* * * * *

AT the annual meeting of the Prehistoric Society of East Anglia, held at the rooms of the Geological Society on March 23, Professor J. E. Marr delivered his Presidential Address, which dealt mainly with the relationship of the deposits containing human relics to the Glacial period. He considered that as the result of Mr. Reid Moir's discoveries the existence of Pliocene man in Britain has been proved. After noting the possible existence of glacial conditions in this country in late Pliocene times, he devoted the main portions of the address to the Pleistocene period. He regards the evidence as favouring the occurrence of a glaciation (the Cromer Drift glaciation) at the beginning of the Pleistocene period, followed by genial conditions during Chellean and Acheulean times. After this followed the glaciation which caused the formation of the Chalky Boulder-clay, which coincided generally with Lower Mousterian times. A slight rise of temperature occurred during Upper Mousterian, Aurignacian, and Solutrean times, though not necessarily sufficient to cause the ice to disappear from more northerly parts of our Island, and during the Magdalenian period the ice re-advanced southward to some extent. If the period from Lower Mousterian to Magdalenian times be regarded as marked by only one glaciation, it would appear that the Chelles–Acheul period immediately preceded the last glaciation, a view in harmony with that of the latest Continental writers. Professor Marr's views are largely based upon Mr. Moir's discoveries in the Ipswich area, but he brought confirmatory evidence from other places. The latter part of the address dealt briefly with changes of sea-level during the times when man dwelt in Britain, and allusion was made to certain river-diversions which were brought about in the same times. The President concluded by emphasizing the vagueness of some of our interpretations, and urgently advocated the collection of more facts, a task which the members of the Society had already largely undertaken during the few years of the Society's existence.

* * * * *

At the meeting of the Geological Society of London on March 24 the President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund available in the present year to Miss Marjorie Elizabeth Jane Chandler, who proposes to investigate the Oligocene Flora of the Hordle Cliffs (Hampshire), and to Laurence Dudley Stamp, B.Sc., Assoc.K.C.L., F.G.S., who proposes to make a comparative study of the Downtonian and Gedinnian in North-Western Europe.

We have received the following letter from a valued correspondent, too late for insertion in the ordinary place in the Magazine, so we venture to put it in our Editorial Notes instead:—

Sir,—I believe the following couplet was written about the time of the publication of Buckland's Bridgewater Treatise on Geology. Could any of your readers give me the author's name?

All, all, was dark and drear before the *Flood*,
Till Buckland came, and made it *clear as mud!*

X Y Z.

Addendum to Obituary Notice of R. Etheridge, jun. (*p.* 240).

Mr. R. Bullen Newton, F.G.S., of the British Museum (Natural History), London, S.W. 7, writes: "An excellent notice of R. Etheridge, jun., appears in the *Sydney Daily Telegraph*, written by Professor Edgeworth David, F.R.S. So far as I can trace. R. E., jun., was a member of the Royal Society of New South Wales, an Honorary Fellow of the Royal Society of South Australia, and a Corresponding Member of the Royal Society of Victoria. In past years he had been a Fellow of the Geological Society of London, and had also been President of the Royal Physical Society of Edinburgh. At the time of his death he was a member of the Malacological Society of London."

Charles Lapworth: an Appreciation.

As announced in our April number, Professor Charles Lapworth died at his residence, Edgbaston, Birmingham, on March 13.

For an account of his life and work our readers are referred to an article—one of the "Eminent Living Geologist Series"—which appeared in the July number of the Magazine in the year 1901. At the time when that article was written the main results of his work in the field, the outcome of thirty-three years of labour, had already been published, and we need therefore add but little to its records.

In 1902 he was elected President of the Geological Society, a position which he would certainly have occupied many years before that date had circumstances permitted. In the following year he delivered his presidential address to the Society, to which further allusion will be made presently. Unfortunately illness prevented him from retaining the Presidency for the usual two years, and geologists were accordingly deprived of a second address, which would doubtless have attained the high level of that which was actually delivered.

In the year 1902 he was also appointed a member of the Royal Commission to inquire into the coal resources of this country, and the importance of his contributions to the report of the Geological Committee of that Commission on the resources of the concealed and unproved coalfields, published in 1905, is widely recognized.

His work on applied geology became more varied as time advanced, and he was in great request as a consulting geologist on questions which concern the miner, the engineer, and others. The city of Birmingham in particular was indebted to him for work of this character, with the result that the hard-headed business-man was taught the value of geology in a manner which specially appealed to him.

Among the later honours conferred upon him we may mention the honorary degree of LL.D. of the University of Glasgow in 1912, and the award of the Wilde Medal of the Manchester Philosophical Society in 1905. We would note, also, that since our former account of Lapworth was published, the monograph of the British graptolites, by Miss Elles and Mrs. Shakespear, has been completed. It forms a fitting conclusion to his great work on this group of organisms, for, as its authors fully admit, it was inspired by Lapworth and he superintended its production throughout.

In attempting an appreciation of Lapworth's life-work, it must be stated at the outset that he was pre-eminently a stratigrapher and field-geologist, though he utilized all branches of geology in pursuing his work, and in so doing added materially to our knowledge of them. His work on the Lower Palæozoic rocks of the Southern Uplands of Scotland forms the foundation upon which his later work was based, and the unravelling of the complex of those uplands was logically followed by that of the much greater complex of the North-Western Highlands.

At the outset he found that field-work in the Southern Uplands required to be supplemented by study of the fossil evidence, and accordingly devoted himself so assiduously to the study of the graptolites that he rapidly became the leading authority upon this group of organisms, and remained so to the day of his death. In acquiring his knowledge of these animals, he mastered the biological memoirs treating of their nearest living allies, and thus incidentally trained himself as a first-rate palæontologist. How accomplished he was as such was later shown by his ingenious restoration of the structure of the trilobite, *Olenellus* (*Callavea*) *Callavei*, from study of the imperfect fragments which he discovered in the Cambrian rocks of Comley.

Again, when solving the riddle of the North-West Highlands, various petrographical questions confronted him, and his study of petrology enabled him here to contribute much to our knowledge of the processes of metamorphism.

The severe illness developed as the consequence of his work in the Highlands had a permanent effect upon Lapworth, and brought to a close the strenuous days of his field-work. Although he subsequently accomplished much among the old rocks of the classic region of Siluria and elsewhere, the work was not marked by the intense vigour which characterized the prosecution of his earlier labours. When we recognize that in his earlier years he was hampered by want of leisure, and in his later by lack of health, we are amazed at what he actually performed.

But though his field-work was impeded in later years, the activity of that most original mind was unimpaired. Lapworth's early training in geometry always stood him in good stead, and enabled him readily to visualize in three dimensions. His work in the Uplands and Highlands of Scotland aroused his interest in tectonic problems, and led to the elaboration of his fold theory. He treated of this at much length in his Presidential Address to the Geological Section of the British Association at Edinburgh in 1892, and finally turned to it once again in that part of his Presidential Address to the Geological Society which deals with geology and physics. Many of the sentences in this are pregnant with meaning, and give us a glimpse of the workings of the mind of a seer. How one regrets that he had neither time nor opportunity to write a great work upon theoretical geology embodying his riper conclusions!

Those who wish to gain a just idea of Lapworth's work should read not only the account given in this Magazine in 1901 but also his own address to the Geological Society. Parts of that address may be regarded as autobiographical, for when he writes of the varied duties of a geologist he is often unconsciously describing his own methods of work in research, scientific practice, and education.

We claim Lapworth as one of the foremost geologists of all time. His output of published work must be estimated by quality rather than quantity, for there is no doubt that his ill-health of later years prevented him from publishing as fully as would otherwise have been the case.

The profound influence exerted by what is published is generally realized, and we need dwell no longer upon this part of his work. But much of his knowledge which he did not commit to print is not lost, but is bearing fruit, and will continue to do so. For Lapworth was a great teacher, and his students have proved this in many ways. His influence, however, was not by any means confined to the lecture-room, and during the years of his Professoriate at Birmingham the city was a geological Mecca, where geologists of all classes went to discuss their work with one who was always ready to help, and they ever came away enriched with new ideas, which will aid materially in swelling the stock of geological knowledge.

Many of us will recall the evenings when, after a hard day's work in the examination-room or elsewhere, and having partaken of a cheerful dinner, Lapworth would perhaps sit down at the piano and play his accompaniment to some gay song from the latest popular opera, and the listener would think that the day's work was over, until a move was made to the study and the Professor poured out treasures from the storehouse of his mind until the small hours of the morning, and the brain of the awed listener reeled. Or, after the consumption of the midday sandwiches on some mountain-slope, he would explain the structure of the surrounding country during the frequent intervals between the relighting of his pipe, until its aspects during the different geological periods seemed to glow before the hearer's vision.

Experts and tyros alike have had these experiences, sitting at the feet of the master. This was, indeed, a liberal education, and one which will prevent his unpublished ideas from being for ever lost. How sad it is to realize that the experiences are now things of the past! But the memories of them are dear, and we treasure the recollection of the waves of joy and earnestness alternating on his animated face, like the changes of light and shade on a hillside beneath a dappled sky.

Would that we could present a faithful picture of him to those who had not the privilege of knowing him, but the task is impossible. We have lost a great geologist, and withal a man of very beautiful character.

ORIGINAL ARTICLES.

Intra-Jurassic Movements and the Underground Structure of the Southern Midlands.

By Professor Arthur Hubert Cox, M.Sc., Ph.D., F.G.S., and Arthur E. Trueman, D.Sc., F.G.S., University College of South Wales and Monmouthshire, Cardiff.

I. Introduction.

RECENT investigations into the relationship between geological structure and magnetic disturbance have called attention to the existence of a line of anticlinal folding that affects the Triassic and Lower Jurassic rocks in the neighbourhood of Melton Mowbray, Leicestershire.[1] It has further been shown to be highly probable that this post-Triassic anticline follows and is founded upon the line of an older and more pronounced anticlinal uplift of pre-Permian date.[2] The presence of the post-Triassic anticline is indicated on the geological map by the sudden swing round of the outcrops of Triassic and Liassic rocks from the normal north to south (or N.N.E. to S.S.W.) direction into a north-west to south-east direction, and then back again to the normal (N.N.E. to S.S.W.). The sudden change of strike is noticeable in the outcrops of all the formations from the Keuper Marl to the Inferior Oolite inclusive, but it becomes least apparent and is gradually lost in the succeeding divisions of the Middle Jurassic. This suggests that the movements that gave rise to the anticlinal structure had died down during or prior to the deposition of the Bathonian rocks.

A similar swing is seen in the Vale of Moreton, and again in the north Cotteswolds, and these were shown by Mr. S. S. Buckman to be due to anticlinal and synclinal folding;[3] the same writer has repeatedly shown by his detailed zonal studies that the Inferior Oolite and other divisions of the Jurassic rocks frequently show evidence of anticlinal flexuring and penecontemporaneous erosion.[4] For instance, he showed that the sequence of the Upper Liassic zones is complete, or nearly so, at Bredon Hill, which is situated on a synclinal axis, while elsewhere non-sequences frequently occur, especially along lines of anticlinal folding. He has further suggested that movement has occurred along many of these lines at intervals during Mesozoic and even Tertiary times.[5]

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[1] Cox, "A Report on Magnetic Disturbances in Northamptonshire and Leicestershire and their Relations to the Geological Structure": Phil. Trans., ser. A, vol. 219, 1919, Appendix, pp. 73–135.

[2] Loc. cit., p. 122.

[3] Buckman, "The Toarcian of Bredon Hill": Quart. Journ. Geol. Soc., vol. lix, 1903, p. 449.

[4] A list of Mr. Buckman's chief papers on these subjects is given in Quart. Journ. Geol. Soc., vol. lxvi, 1910, p. 53.

[5] Op. supra cit., 1903, p. 449.

Mr. L. Richardson has since shown that some of these folds, notably those in the northern Cotteswolds, at Bredon and Moreton, are indicated also by the Rhætic rocks, which attain a great development at Dunhampstead, on the line of the Bredon syncline, and which show a non-sequence at Church Lawford, in the Vale of Moreton, along the anticlinal flexure. Richardson also stated that the Moreton anticline was probably a continuation of the Pennine axis.[1]

II. OTHER POSSIBLE ANTICLINAL AXES.

Examination of the geological map discloses the existence of other localities where the outcrops of the Liassic rocks suffer a local twist from what one may regard as the normal north-easterly to south-westerly strike. Such swings are noticeable at the following localities taken in order from north to south:—

1. Melton Mowbray.
2. ? Market Harborough.
3. Weedon.
4. Banbury.
5. Vale of Moreton.
6. Winchcombe.

But whereas the anticlinal structure has been definitely shown to exist, as noted already, at several of these localities, it has not been proved in the remaining cases. Yet, judging by analogy, it at once appears probable that the places mentioned are situated on or near the lines of anticlinal axes. In the following pages the available evidence as to the existence of such lines is examined, the age of the movements is considered, and the possible bearing of the flexures upon the deep-seated structures is discussed.

It is at once apparent that the postulated anticlines are not equally well developed, but that the flexuring is most powerful in the case of the two western anticlines, the Vale of Moreton and the Winchcombe folds. In these two cases the outcrops are twisted to such an extent that further evidence of the presence of anticlinal folding is hardly needed. These anticlines are evidently structures of considerable magnitude, and each is clearly accompanied by its complementary syncline, the Chipping Campden syncline and the Bredon syncline.[2] But in the case of the other anticlines mentioned above, the evidence from the map is not so clear, and additional evidence is needed before the anticlinal character of the respective localities can be considered as established.

One reason for the necessity of further evidence is that each of the postulated anticlines through Banbury, Weedon, and Market Harborough respectively, is related to the line of a river valley or valleys; the combination of river valley, horizontal strata, and relatively high relief might suffice to explain in each case the local

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[1] Richardson, "The Evidence for a Non-Sequence between the Keuper and Rhætic Series in North-West Gloucestershire, etc.": Quart. Journ. Geol. Soc., vol. lx, 1904, pp. 349–58.

[2] The Bredon syncline, as Mr. Buckman has shown, is a prolongation of the Cleeve Hill syncline (Buckman, op. cit., 1903).

bending of outcrops without the aid of any anticlinal flexuring. On the other hand, the existence of the valleys may be significant when account is taken of the known preference of river valleys for anticlinal areas, as instanced by the anticlines already proved through Melton Mowbray and the Vale of Moreton.

Although the outcrops of the various members of the Lower Jurassic, particularly the Lower and Middle Lias, suffer marked deviations in the valleys mentioned above, it is noticeable that the outcrops of the Middle and Upper Jurassic rocks are not affected in any way. This at once suggests that the flexuring took place during Jurassic time, and that the movements had died down prior to the deposition of the Cornbrash and Oxford Clay.

If such intra-Jurassic folding has occurred it would give rise to non-sequences along the anticlinal axes, while in the complementary synclines the succession should be more nearly complete. This has proved to be the case wherever the strata have been sufficiently studied, as in the Vale of Moreton anticline and the Bredon syncline, investigated by Buckman.

III. FURTHER EVIDENCES OF INTRA-JURASSIC MOVEMENT.

In attempting to use zonal methods to demonstrate the existence of Jurassic folding in the area between the Vale of Moreton and Melton Mowbray, we are unfortunately met by a great lack of detailed information which can be regarded as trustworthy in the light of recent refinements of zonal work. Further, it has frequently happened that the thickness of a subdivision or zone as determined at *one locality* has been quoted as the thickness throughout a *whole county*. In point of fact, thicknesses may vary greatly within the county limits. For these reasons we have been unable to use many of the figures that at first sight would appear to be available. Owing to this lack of reliable information only certain well-marked zones can at present be used for our purpose.

It is obvious that non-sequences and local variations in thickness will show best in thin zones. Further, the most useful deposits will be those which were laid down after periods of considerable movement; thus Mr. Buckman has found that some of the most notable non-sequences correspond with the Bajocian uplift and denudation.[1] During the deposition of the Lias, the maximum movement occurred between the times of accumulation of the Middle and Upper Lias, that is after the hemera of *spinati*, when slight uplift took place, and gentle folding resulted in the formation of several shallow basins in which first a thin deposit of the Transition Bed (*acutum* zone) and then the lower zones of the Upper Lias were laid down.[2] These beds would naturally be absent or very

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[1] Buckman, "The Cleeve Hill Plateau": Quart. Journ. Geol. Soc., vol. lviii, 1897, pl. xlvi; and also "The Bajocian of the North Cotteswolds": ibid., vol. lvii, 1901, p. 146.

[2] Trueman, "The Lias of South Lincolnshire": GEOL. MAG., 1918, p. 108.

attenuated near the anticlinal axes, and would be best developed in the synclinal areas.

The variations in the thicknesses of these zones will now be considered in order to see whether there exists any definite relationship between such variations and the positions of the postulate folds.

(1) *Acutum Zone.*—The *acutum* zone is especially suitable for the present purpose for several reasons. As the "Transition Bed" between the Middle and Upper Lias, and containing many fossils, it has received much attention. It has also been well exposed in many workings for Marlstone Ironstone, while it is very thin and its fossils easily recognized, so that there are few records that cannot be utilized.

The distribution of the deposits of *acuti* age constitutes a striking confirmation of the suggested folding.[1] While the *acutum* zone is well represented around Lincoln, it is probably absent at Grantham, appearing again as a thin layer at White Lodge near Waltham-on-the-Wolds, Leicestershire, in the Old Dalby syncline. In the neighbourhood of the Melton Mowbray anticline the *acutum* zone has not been recorded, a fact which makes it extremely probable that the zone is not represented there. South of this region, however, in the Tilton syncline, the zone attains its best development around Tilton. It has again not been recorded anywhere in the neighbourhood of the postulated Market Harborough anticline, and it is likewise thin or absent along the line of the supposed Weedon anticline, but its presence has been proved in the intervening district, which includes what we propose for convenience to refer to as the Cold Ashby syncline.

Again, between Northampton and Banbury the *acutum* zone is well seen, and has been described by many observers at Chipping Warden and Byfield. Towards the suggested anticline through Banbury, however, the deposits again thin out, and at King's Sutton a very attenuated representative rests on an eroded surface of Marlstone. West of this line the *acutum* zone once more thickens in the region of the Edgehill syncline, but still further south or west it has not been found.

At several localities, such as Aston le Wall and Milton, situated near the lines of the postulated anticlines, the deposits contain rolled materials or pebbles, a further evidence of slight erosion.

(2) *The Tenuicostatum Zone.*—The *tenuicostatum* zone (formerly miscalled the *annulatum* zone) occurs at the base of the Upper Lias immediately above the Transition Bed (*acutum* zone). In many

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[1] The thicknesses of zones have been obtained mainly from the following sources: Judd, *The Geology of Rutland*, *etc.* (Mem. Geol. Surv.), 1875. Walford, Proc. Warwick. Nat. Field Club, 1878, p. 37. Thompson, Journal Northants Nat. Hist. Soc., vol. ii, 1882–3. Wilson & Crick, Geol. Mag., 1889, p. 296. Thompson and others in Report of Brit. Assoc., 1891, pp. 334–51. Woodward, *Lias of England and Wales* (Mem. Geol. Surv.), 1893. Richardson, *Handbook to the Geology of Cheltenham*, *etc.*, 1904. Trueman, Geol. Mag., 1918, pp. 106–8.

records no attempt has been made by authors to identify the Dactyliocerates of this zone, but as the deposits are frequently paper shales, and constitute the lower part of the "Fish Beds", or Dumbleton Beds of Professor Judd,[1] it can generally be identified from descriptions of the sections.[2]

It has been shown by Mr. Buckman and others that the *tenuicostatum* zone attains its maximum thickness in Yorkshire, is thick in Lincolnshire, and thence southwards is recognizable as a very thin layer.[3] But this generalization is upset by a sudden thickening of these beds along the Bredon syncline, for at Dumbleton they are extremely well developed, a fact which further suggests the existence of a basin there in Liassic times.

As the *tenuicostatum* zone is traced southwards from Lincolnshire, in those districts where a sufficient number of thicknesses is available, further indications are obtained of intra-Liassic movement; this again appears to have occurred along the axes that have been previously noticed. There is, for instance, a slight thickening in the Old Dalby syncline, although the zone generally is rapidly thinning out southwards. The probable absence of the zone in the district around Weedon near the Weedon anticline is interesting, as the zone is certainly present at Chipping Warden and further to the south-west. The zone once more thins towards Banbury, and Mr. J. Pringle informs us that he believes it to be absent just north-west of Banbury, where the overlying *exaratum* zone, itself attenuated, rests with a non-sequence on an inconstant representative of the *acutum* zone which fills small hollows in the underlying Marlstone. There was, therefore, but little deposition over this region during a period in which deposits belonging to several zones were accumulating elsewhere. Still further south-west, paper-shales occur at Chipping Norton in the Edgehill syncline, but thin out once more towards the line of the Moreton anticline, only to thicken in the Bredon syncline, as we have already indicated.

The results obtained from our study of the *acutum* and *tenuicostatum* zones are summarized in the table on p. 203, in which it is seen that the variations in these two zones take place at exactly those localities where they would be expected if the folding which is indicated by the course of the outcrops was in progress during the periods of deposition. In each case the deposits thicken towards the synclines and thin away towards the anticline.

(3) *Other Zonal Evidence.*—While it is not yet possible to follow other zones in similar detail across the whole of the Midlands, there are certain zones traceable for short distances which afford further evidence of some of the supposed intra-Liassic movements.

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[1] Judd, *The Geology of Rutland, etc.* (Mem. Geol. Surv.), 1875, p. 83, etc.

[2] Although in some of our figures, perhaps a portion of the *exaratum* zone may also be included.

[3] Buckman, "Certain Jurassic (Lias-Oolite) Strata of South Dorset, etc."; Quart. Journ. Geol. Soc., vol. lxvi, 1910, p. 88.

ggested folds.		Old Dalby Syncline.	Melton Mowbray Anticline.	Tilton Syncline.	Market Harborough Anticline.	Cold Ashby Syncline.	Weedon Anticline.	Badby Syncline.	Banbury Anticline.	Edgehill Syncline.	Moreton Anticline.	Chipping Campden Syncline.	Winchcombe Anticline.	Bredon Syncline.
cutum zone	? Absent	*	? Absent	*	? Absent	*	Thin	*	Absent	*	Absent			
enui-statum zone	*	Thicker	?	*	*	*	? Absent or thin	*	Absent or Thin	*	Thin	*	Thin	Thick

* Denotes zone present.

For instance, the *planorbis* zone in the Old Dalby syncline shows a characteristic thickening from Owthorpe and Cotgrave Gorse on the north to East Leake, near the synclinal axis.[1] Further south again, at Barrow-on-Soar, the zone is again thinner. These facts are extremely suggestive of movement along the axis in Lower Liassic times, but unfortunately no details of this zone are available further south.

The chief lack of information concerning many zones is due to the broad way in which they have been interpreted. Minute zonal studies on the lines indicated by Mr. Buckman's recent work[2] cannot fail to yield a great deal of useful information, for in many cases the zones he defines are so thin and have a fauna so distinct that given sufficient exposures it will be a comparatively easy matter to trace their extent.

Meanwhile it has only been possible to collect isolated facts, but some of these are significant. For example, the capricorns of the *Liparoceras* series, which mark a definite but comparatively short period of time, have only been found at Dumbleton and Napton-on-the-Hill, Warwickshire, both of which are situated on supposed synclinal lines.[3]

(4) *Other Types of Evidence.*—Working on the same principle, attempts were made to trace any relationship between the folds and the thicknesses of the strata, using the total thickness of whole formations. The attempts were unsuccessful, partly on account of the few data available, there being a surprising lack of records that give, for instance, the total thickness of the Lower or Upper Lias; further, the small variations that may be expected as a result of any contemporaneous folding are superposed on large-scale regional variations due to regional tilting, or to secular elevation which was in progress at the time of deposition. For instance, during Toarcian (Upper Lias) times the area of maximum deposit moved southwards

[1] Trueman, Geol. Mag., 1918, pp. 67–70.

[2] Buckman, "Jurassic Chronology: I. Lias": Quart. Journ. Geol. Soc., vol. lxxiv, 1919.

[3] Trueman, "The Evolution of the Liparoceratidæ": Quart. Journ. Geol. Soc., vol. lxxiv, 1919, p. 252, etc.

from Yorkshire as a consequence of some regional movement; the results of the regional movement almost completely conceal the results of any minor flexuring during that time. Attention has in the past naturally been drawn to the larger lateral variations, with the result that any minor or local variations superposed on the regional ones have been overlooked.

As remarked above, we have failed to accumulate sufficient evidence to prove the occurrence of such local variations in the formations considered as a whole. But so far as the records go, they tend to confirm the results obtained by a critical examination of subdivided zones, such as the *acutum* and *tenuicostatum* zones detailed above. For example, the collected figures suffice to show that the Upper Lias thickens in the Old Dalby syncline and in the Bredon syncline. As regards the Lower Lias, there are evidences of local thickening in the synclinal areas of Bredon and Badby. As regards the Rhætic there is again a thickening in the Bredon syncline, and perhaps also in the Old Dalby syncline. It seems probable, therefore, that when sufficient data are available concerning thicknesses of other zones and subdivisions, it will be possible to trace the effects of the local movements in most of the divisions between the Rhætic and the Inferior Oolite. In this way it may prove possible to separate the effects of local uplifts from those due to regional movements involving widespread tilting with consequent transgression or regression.

(5) *Evidence of Movements from post-Bathonian Rocks.*—We have shown above that an examination of certain thin zonal deposits appears to confirm the evidence of outcrop that folding was in progress at intervals in Liassic time. Variations in thicknesses of the major divisions yield some additional support. Taken in conjunction with the results already mentioned as obtained by Mr. Richardson, that local movements were taking place in Rhætic times along the same lines that were afterwards followed by Bajocian movements, we find that there was gentler but almost continuous movement along definite lines up to about the end of Bajocian time. Then these particular movements appear to have ceased, for the outcrops of the Bathonian and higher formations are but little affected.

Nevertheless, it is still possible to trace the southward prolongation of the folds beyond the area occupied by Bajocian rocks, because movement along the same lines seems to have been renewed at certain later periods, so that along the anticlinal lines denudation was repeatedly at a maximum. Thus it is more than a coincidence that along the southward prolongation of the Moreton anticlinal axis the Lower Cretaceous Sands should at Faringdon suddenly come to rest directly on the Corallian, while still further south, just where the prolongation of the same line crosses the Vale of Pewsey uplift. the Tertiary beds overstep nearly the whole of the Chalk and come into their closest proximity to the Upper Greensand.

Similarly at Wallingford on the southward prolongation of the Banbury axis, the course of the Upper Greensand outcrop clearly indicates the existence of gentle anticlinal folding.

In the region further east, Mr. R. H. Rastall has called attention to the anticlinal disposition of the Upper Jurassic with regard to an axis of maximum erosion which passes north-westwards through Sandy (10 miles east of Bedford), and he has explained the structures as due to a pre-Cretaceous posthumous uplift of the Charnian axis.[1]

IV. Relation of the Folds to Palæozoic Outcrops.

It is only to be expected that several of these axes of Mesozoic uplift should be aligned with uplifts that have resulted in exposing the nearest outcrops of Palæozoic rocks. Thus the Moreton and Winchcombe anticlines are aligned respectively with the Warwickshire and South Staffordshire Coalfields, and the Chipping Campden and Bredon synclines with the troughs between the Warwickshire and South Staffordshire and South Staffordshire and Forest of Wyre Coalfields, while the connexion between the Melton Mowbray anticline and the uplift of pre-Cambrian rocks in Charnwood Forest has been discussed elsewhere.[2] The connexions between the remaining anticlines, the Banbury, Weedon, and Market Harborough folds and the nearest Palæozoic rocks are not so clear, but it will be shown that there are reasons for connecting both the Banbury and the Weedon folds with the Warwickshire Coalfield, and the Market Harborough fold with the Charnwood Forest area.

Several of these areas of Jurassic folding have already been explained as due to posthumous movements along axes of Palæozoic uplift. This was suggested as early as 1901 by Mr. Buckman, in discussing the Bajocian rocks of the North Cotteswolds;[3] Mr. Buckman showed that penecontemporaneous "erosion is likely to have taken place along similar lines at different times, and therefore may be connected with the folds in the Palæozoic rocks, and may have a bearing on the thickness of the rocks overlying the coal measures".[4] Professor W. S. Boulton has more recently suggested that minute Jurassic zonal studies will all have their value when estimating the nature and thickness of cover over the buried coal measures.[5] A similar suggestion was made by Professor P. F. Kendall regarding anticlinal axes in East Anglia,[6] by Mr. Rastall[7] for the pre-Cretaceous uplift which caused excessive denudation of Upper Jurassic rocks along a continuation of the

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[1] Rastall, *Cambridgeshire*: Geology in the Field, pt. i, 1910, p. 143.

[2] Cox, Phil. Trans., ser. A, vol. 219, Appendix, 1919.

[3] Buckman, "The Bajocian of the North Cotteswolds": Quart. Journ. Geol. Soc., vol. lvii, 1901, pp. 147–9.

[4] Op. cit., p. 154.

[5] Presidential Address to Section C (Geology), Report Brit. Assoc., Newcastle-on-Tyne, 1916, p. 383.

[6] Report of the Royal Commission on Coal Supplies, pt. ix, Appendix iii.

[7] *Cambridgeshire*: Geology in the Field, pt. i, 1910, p. 143.

Charnian axis, and again by one of us in the recently recognized Melton Mowbray uplift.[1]

It will be noticed that the axial lines of the flexures change in direction from east-west at Melton Mowbray to north-west—south-east at Market Harborough, then to approximately north-north-west—south-south-east at Daventry and at Banbury, and finally to a north-south direction in the two cases of the Vale of Moreton and the Winchcombe structures. The variation in the direction of the different axes may be ascribed to splitting and fingering-out southwards of the main axis of post-Triassic uplift, the Pennine axis. The fingering-out of the post-Carboniferous pre-Permian Pennine uplift has been described by Professor Kendall[2] and by Professor Fearnsides,[3] and it was ascribed by the latter writer to a lagging of the eastward-moving folds as they approach the buried area of older rocks which we know to underlie East Anglia. If, as the structures indicate, the Triassic and Jurassic movements followed the lines of the earlier pre-Permian movement, the radial arrangement of the fold-axes is readily explained. The existence of such a radial arrangement serves to account for the increased number of anticlinal areas in the south and east as compared with the central Midlands. If it were possible to differentiate and map particular horizons in the thick Keuper Series, as has been accomplished by Dr. Matley[4] over part of Warwickshire, it would probably prove easy to trace all the folds from the Jurassic rocks across the intervening Keuper to the Palæozoic areas, and so to see the southward splitting of certain of the fold-axes.

Further, it should be noted that, while the Nottinghamshire, Warwickshire, and South Staffordshire Coalfields all have a north-south alignment, due to post-Triassic movements which have affected the Mesozoic cover, the Palæozoic rocks in each coalfield show the presence of other axes due to older north-westerly movements oblique to the present alignment. For example, the Warwickshire Coalfield has two marked Charnian anticlinal axes, each of which brings up Cambrian rocks. One of these axes is on the present north-eastern margin of the coalfield at Nuneaton and the other on the western margin at Dosthill,[5] so that the structure within the coalfield is complex, due to two systems of uplifts which cross one another obliquely, one pre-Triassic and one post-Triassic. Now in each case it is probable that while the north-south post-Triassic movements were in progress, there was simultaneous posthumous

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[1] Cox, Phil. Trans., ser. A, vol. 219, Appendix, 1919, p. 124.

[2] Report of the Royal Commission on Coal Supplies, pt. ix, Appendix iii, 1905.

[3] "Some Effects of Earth-movement on the Coal Measures of the Sheffield District," Part II: Trans. Inst. Min. Eng., vol. li, pt. iii, 1916, p. 107 (with references).

[4] Matley, "The Upper Keuper (or Arden) Sandstone Group and Associated Rocks of Warwickshire": Quart. Journ. Geol. Soc., vol. lxviii, 1912, p. 269.

[5] *Geology of the Country around Lichfield* (Mem. Geol. Surv.), 1919, p. 7.

movement along the older Charnian axes.[1] If this were so it would explain why more than one of the Jurassic anticlines connects with the present visible Warwickshire Coalfield.

If now we are justified in our conclusions that each of these slight uplifts in the Mesozoic rocks of the Midlands indicates the line of a deeper-seated and more powerful uplift in the underlying Palæozoic rocks, the importance of their further study is obvious, and it is seen that detailed zoning and detailed records of thickness may prove of import for the tracing of the larger underground structures. Any facts which may shed light on the underground structure of this region are doubly valuable because of the possibility of the existence of concealed coalfields. Taken in conjunction with the gradually accumulating evidence as to the depth of the Palæozoic floor,[2] the Mesozoic folds may yet serve as guides to the most likely areas for finding productive coal-measures at reasonable depths.

V. GENERAL CONSIDERATION OF THE UNDERGROUND STRUCTURE OF THE SOUTHERN MIDLANDS.

Surveying the underground structure of the country as a whole, attention may be called to a peculiar symmetry in the general deposition of the Palæozoic rocks. In the centre of England we have the Pennine axis which fingers out southwards into a number of subordinate folds in Carboniferous rocks. They are flanked to the south-east by a large area of older rocks, Devonian and Silurian with some Cambrian and pre-Cambrian, which underlies, so far as we know at present, most of the district between Northamptonshire, Buckinghamshire, Herefordshire, and East Anglia.[3] This mass of older rocks occupies much the same position on the south-east side of the Pennine axis as the mass of Devonian, Silurian, and older rocks in Wales, on its south-west side. Not only so, but just as the Welsh rocks have a predominant south-westerly strike which gradually swings to east and west in South Wales, so the East Anglian mass, judging from present information, is affected by south-easterly structures which probably swing round to east-west under the region of the Thames estuary. The Kent Coalfield, with its highly inclined Carboniferous rocks, may thus compare structurally with the Pembrokeshire Coalfield, with its highly compressed structures. In each case the compression of the Carboniferous rocks may be accounted for by proximity to an area in which the Lower Palæozoic rocks strike east and west.

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[1] Compare Matley, op. supra cit.: also A. Morley Davies & J. Pringle, "Two Deep Borings at Calvert . . .": Quart. Journ. Geol. Soc., vol. lxix, 1913, p. 335; also Baker, "Charnian Movement in East Kent": GEOL. MAG., Dec. VI, Vol. IV, 1917, p. 398.

[2] Strahan, Presidential Address: Quart. Journ. Geol. Soc., vol. lxix, 1913, p. lxx. See also A. Morley Davies & J. Pringle, ibid., p. 334.

[3] Strahan, op. cit.

Various further coincidences in symmetry appear, such as disposition of the pre-Cambrian and Cambrian rocks of Leicestershire, with their south-easterly strike as compared to the pre-Cambrian and Cambrian rocks of Shropshire, with their south-westerly strike. Yet other resemblances become apparent from a study of the map, and it seems likely that a fuller knowledge of the distribution of the concealed Palæozoic rocks would yield yet other similarities.

VI. SUMMARY.

1. The occurrence of anticlinal folding during Jurassic times has been demonstrated by Mr. Buckman's detailed zonal work in the Vale of Moreton and in the North Cotteswolds. These anticlines are indicated on the map by marked bends in the outcrops of the Lower Jurassic formations.

2. Similar bendings of outcrops are seen at several localities in the Eastern and Southern Midlands, and the structure at one such locality—Melton Mowbray—has recently proved to be anticlinal.

3. Intra-Jurassic folding betrays itself by non-sequences and reduced thicknesses of Lower Jurassic zones along anticlinal axes. Such evidence suggests the existence of anticlinal structures in the neighbourhood of Banbury, Weedon, and perhaps also Market Harborough, in addition to the cases mentioned above.

4. Movement was probably almost continuous along some or all of these axes, at least from Rhætic to Bajocian times. Outcrops of post-Bathonian formations are not affected by the flexures, although the folding was perhaps renewed in later Jurassic or even Tertiary times.

5. Several of these lines of Jurassic folding probably follow the lines of earlier and more powerful movements. The bearing of such flexures on the structure of the Palæozoic floor is discussed.

6. Attention is called to a curious symmetry in the disposition of the Palæozoic formations on either side of a prolongation of the Pennine axis.

Note on a New Vole and other Remains from the Ghar Dalam Cavern, Malta.

By DOROTHEA M. A. BATE, Hon. M.B.O.U., F.Z.S.

IN 1916[1] the writer published a list of the vertebrates of which remains had been obtained from the Pleistocene cave and fissure deposits of Malta. Early this year (1919) a few rather fragmentary remains were forwarded by Mr. G. Despott to the British Museum (Nat. Hist.) for identification. These are from the Ghar Dalam Cavern, from which a number of specimens have already been obtained.[2] As some of the specimens lately received add to

[1] Proc. Zool. Soc., 1916, p. 421.

[2] Proc. Roy. Soc., vol. liv, 1894, p. 274.

our knowledge of the fauna in question, it may be worth while to record the following notes.

MAMMALIA.

Mammalia are represented by fragmentary remains of *Cervus elaphus*, var. *barbarus*, of two species of rodents and of a small fox. Included among the rodent remains is a right femur of an immature animal, and this appears to agree most closely with that of *Rattus*, which has not been recorded previously from the cave deposits, but two species of which, *R. decumanus* and *R. alexandrinus*, are recorded in Dr. Gulia's list of the recent mammals of the Maltese Islands.[1]

Another species is represented by a left and right mandibular ramus, the former containing the incisor only, while the latter still retains the two anterior cheek teeth as well as the incisor. There are also two right femora and a tibia, which seem to belong to the same species. The mandibular rami have been compared with those of several species both recent and extinct, and so far as can be judged from such scanty material they appear to represent an undescribed species most nearly allied to *Arvicola* (*Tyrrhenicola*) *henseli* Major, from the Pleistocene ossiferous breccias of Sardinia.[2] It is proposed that the Maltese species be known as—

ARVICOLA MELITENSIS, sp.n.

The characters of the lower jaw and teeth show it to be closely allied to *A.* (*T.*) *henseli*, from which it may be readily distinguished by its considerably smaller size. Owing to the imperfect state of the specimens it is difficult to give comparative measurements other than the antero-posterior length of the first two cheek teeth, which in *A. henseli* is 5·5 mm. and in *A. melitensis* 4·5 mm. Although possibly not a constant character, it may be worth mentioning that in Dr. Forsyth Major's figure[3] of the crown-pattern of the lower dentition of *A. henseli* the whole of the dentine area of the anterior loop is confluent, whereas this loop in *A. melitensis* is practically divided into two parts (see Text-figure).

As in *A. henseli* the lower cheek teeth in *A. melitensis* are rather wide crowned, and the enamel is somewhat thinner than in the recent *Pitymys*. Dr. Forsyth Major's subgenus, *Tyrrhenicola*, was based chiefly on cranial characters, and it will be interesting to see if further material from Malta bears out the close relationship indicated by the lower jaw.

Other mammalian remains consist of the anterior half of a left lower carnassial, a left lower canine, and a number of imperfect limb bones of a small species of *Vulpes*. These, as also some specimens belonging to the Manchester Museum kindly lent by Mr. J. Wilfrid Jackson, have been carefully compared with many

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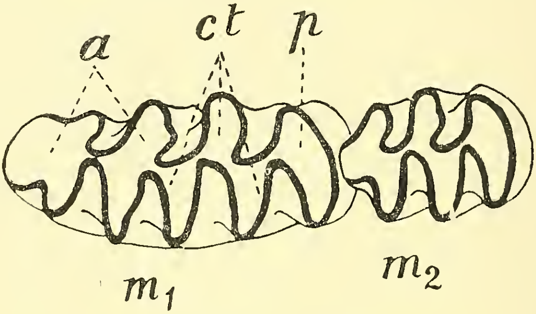
[1] Ninth International Zool. Congress, Monaco, 1913, pp. 545–55.

[2] GEOL. MAG., 1905, p. 504.

[3] Loc. cit., p. 505.

recent and fossil species in the British Museum. They seem to show no characters sufficiently constant or distinctive to warrant their separation as a distinct species, but evidently represent a small race with a weak dentition and slender limbs, smaller than *V. ichnusæ* from Sardinia, and probably approximating in size to *V. nilotica*, of which no skeleton has been available for comparison. The extreme slenderness of the proximal articulating surfaces of two metatarsals from Malta is very noticeable. Much variation in size is indicated by the Maltese specimens.



Arvicola melitensis, sp. nov. Crown view of first and second right lower molars. Enlarged × 15 diam. *a.* anterior loop; *c.t.* closed triangles; *p.* posterior transverse loop.

There is in the British Museum the distal end of a humerus (M. 8159) from the Pleistocene of Corsica, which seems to agree closely in size with the Maltese form. No fox is found living in Malta at the present day, the only land carnivores being *Mustela nivalis boccamela* and *M. africana*, the latter possibly introduced through human agency.[1]

REPTILIA.

Reptiles are represented by a few fragments of carapace, ascribed to *Lutremys europæa*, and by several limb bones, pelvic bones, two vertebræ, and the base of a skull of *Bufo vulgaris*, Laur. These latter specimens have been kindly examined by Dr. G. A. Boulenger, F.R.S., who considers that from the characters of the sacral vertebra they may be confidently assigned to this species. Previously no specifically identified remains have been recorded; Leith Adams in his "List"[2] mentioned only "Batrachia sp. Frogs or Toads, sp."

It is interesting to note that apparently no toad occurs in the Maltese Islands at the present day, the only batrachian being *Discoglossus pictus* Otth.[3]

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[1] See Miller, *Cat. Mamm. West. Europe*, 1912, p. 414.

[2] Quart. Journ. Geol. Soc., vol. xxxiii, 1877, p. 177.

[3] See Dr. Gulia, loc. cit.

Aves.

Bird remains are represented by only a few imperfect bones, but these are worth mentioning, some being those of passerines; one the proximal portion of a right humerus of *Turdus ? musicus*. So far as I am aware remains of passerine birds have not been previously obtained from Maltese deposits.

My best thanks are due to Dr. Smith Woodward, F.R.S., for allowing me to examine this interesting little collection, and to Mr. M. A. C. Hinton for valued help in their determination.

Notes on Lateritization in Sierra Leone.

By F. Dixey, M.Sc., F.G.S., Government Geologist, Sierra Leone.

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(PLATE III.)

Contents.

I. Introduction.

In the course of the Geological Survey of Sierra Leone in 1918–1919 certain features of interest were observed in the lateritization of the norite [1] of the Colony and of the Pleistocene deposits which form the coastal plain surrounding the norite mass. These features form the basis of the following notes.

Laterite is a rock of variable composition, consisting of a mixture of hydrated oxides of iron, aluminium, titanium, and, rarely, manganese, and formed by the superficial decomposition of certain rocks; it is a residual accumulation resulting from the removal in solution from the rocks affected of combined silica, lime, magnesia, soda, and potash. It may be formed by the alteration in situ of original rocks or by the alteration of detrital deposits; the first of these two products is termed high-level or residual laterite, and the second, low-level or detrital laterite, or, as suggested by Dr. L. L. Fermor, "lateritite." [2] The detrital laterite is made up of the detritus of other forms of laterite, mixed with the quartzose and argillaceous detritus of granitic and other rocks; the whole is cemented together by the action of water on the lateritic constituents.

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[1] The present author hopes to publish an account of this norite at an early date.

[2] Fermor, "What is Laterite?": Geol. Mag., 1911, p. 507.

2. (i) LATERITIZATION OF THE NORITE. (Pl. III, Fig. 1.)

The country rock of the Colony is a medium-grained norite, associated with which is a relatively small development of a coarse norite and an aplitic variety; the medium-grained type offers the best means of following the process of lateritization.

In consequence of rapid erosion induced by high relief, laterite formed in situ has been unable to accumulate to any considerable depth except in special circumstances. On valley-sides, hill-crests, and cols, the laterite is rarely more than a few inches deep. On rounded hills and gentle slopes the country rock crops out in a characteristic manner as numerous large boulders and crags, or even low isolated rounded surfaces. The outstanding character of these various masses is due in all cases to lateritization, which progressed along master joints. The lateritized portion was more readily removed by erosive agencies, and the masses of unaltered rock were left standing in relief. The masses of rock exposed in this way exfoliate in thin shells and gradually assume a rounded form. Their exposed surfaces are either fresh or covered with only a thin skin of laterite. Where the rock is closely jointed, lateritization proceeds uniformly throughout and extends to a depth of several yards. Examples of this occur over part of the gentle slope[1] on which the W.A.R. camp stands, near Wilberforce, and in the valley of the Congo south-west of Freetown. The depth of lateritization was so great on the right bank of the Congo at a height of about 500 feet O.D. that a project for building a small dam across the valley ended in failure, because it would have been necessary for the dam to rest everywhere upon solid rock, and the cost of this was prohibitive.

A clearing was made up the steep valley sides just above a narrow gorge; on the left bank the norite was exposed under a thin cover of laterite, but on the right an excavation cut through 12 feet of laterite before exposing the norite, and even when extended laterally met only the altered rock. The alteration had proceeded along joints until only cores of unaltered rock were left; the cores were in the form of slabs because of the platy jointing prevailing in this place. The slabs or cores were surrounded by more or less concentric layers of red laterite, which became more irregular in shape outwards. Sometimes all that remained of the original mass was a red "ghost" with concentric lamination and an irregular outline.

In most localities in the Colony the core of a lateritized mass tends to become continually more rounded in form as it diminishes in size. But where the norite is banded lateritization sometimes

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[1] Cf. Professor Lacroix, "The formation of a continuous crust depends on definite topographical conditions (horizontal plateau or gentle slope of ground)." Fermor, "The Work of Professor Lacroix on the Laterites of French Guinea": GEOL. MAG., 1915.

proceeds rapidly along certain bands, which when dipping at a high angle are altered to a considerable depth. A number of little coves and a series of parallel reefs running out obliquely from the shore owe their origin to the removal of such weathered bands by wave action. Examples can be seen about Kent and near Aberdeen Creek.

It is possible to trace in the hand specimen the change from a core of unaltered norite to the outer zone of red-brown laterite ("gibbsitic laterite" of Professor Lacroix[1]). The grey core is enclosed by a pale cream-coloured halo with brown pseudomorphs of the pyroxenes. This pale halo gives place gradually through yellow and then brown to the red-brown outer zone; the halo and the outer zone correspond respectively to Professor Lacroix's "zone of leaching" and "zone of concretion".[2] The transition from core to halo is a rapid one and takes place within 0·2 in. The colours of the halo and succeeding zones are due to a whitish alteration-product of the felspars, which becomes stained to an increasing depth as the ferromagnesian minerals decompose. As the alteration progresses the individual crystals gradually become unrecognizable and the mass itself becomes crowded with small concretions and pierced by narrow ferruginous veins, until finally it forms coarsely porous red laterite. This secondary laterite bears close resemblance to that formed from detrital deposits.[3]

As regards individual minerals *felspar* is the first to be affected. It passes into a white opaque alteration product, which spreads along the cleavage cracks, and for a time leaves flakes of the mineral fresh and unaltered. Then a clear white recrystallization sets up along the old cleavage cracks and the remaining parts of the crystal dissolve out, resulting in a framework of parallel plates studded with minute colourless crystals (probably gibbsite). Later iron staining commences, and the pseudomorph gradually breaks up. *Diallage* changes in colour from almost black to brown at a very early stage, and with the rhombic pyroxene causes a mottling of the light-coloured halo; it is then gradually pseudomorphed in parallel brown scales, exceedingly fine, and possessing an earthy lustre. The *rhombic pyroxene* develops a close, platy structure, and retains its bronzy lustre to a late stage. The *iron-ore* is recognizable, and apparently unaltered long after all the other minerals have disappeared. *Olivine* is not recognizable after lateritization has commenced.

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[1] Op. cit., p. 35.

[2] Op. cit., p. 34.

[3] Cf. Arsandaux: "Toutes les formations latéritiques montrent deux zones: (i) La première zone, contigüe à la roche originelle en reproduit exactement la structure; elle en constitue une véritable pseudomorphose; les felspaths de la roche fraîche sont remplacés par une matière blanche; les éléments colorés par du sesquioxyde de fer. (ii) La seconde zone, superposée à la première, est depourvue de tout ordonnancement de ses éléments constitutifs" (*Handbuch der regionalen Geologie*, vii, 6*a*, p. 61).

(ii) ALTERATION OF NORITE RICH IN IRON.

Lateritization proceeds very readily where the norite is rich in disseminated magnetite (titanomagnetite), but it goes on slowly if the proportion of iron be increased beyond a certain point. This is illustrated on the foreshore west of Aberdeen Creek, where certain inclined bands in the norite have been thoroughly lateritized for many yards along their outcrop, and seams of magnetite in them, up to 2 inches thick, run practically unaltered from norite into laterite. Some of the seams contain a little felspar in parallel arrangement with the magnetite. In such cases the magnetite is often left as a spongy mass on the weathering of the felspar. Further within the lateritic masses there occur more or less spherical cores of iron-rich norite, enclosed in concentric shells; such cores apparently owe their unaltered state to a high iron content.

In addition to the seams of magnetite in the normal norite, there occur locally in the coarse norite irregular crystals and small spongy masses of magnetite which also remain unaltered when the enclosing rock is lateritized. Good examples of these masses, and of crystals ranging up to 3 inches in length, can be seen in coarse norite exposed on the foreshore immediately south of York.

3. LATERITIZATION OF GRANITIC ROCKS.

The solid rocks of the Protectorate have been lateritized to a considerable depth in many places. Where they rise above the Pleistocene deposits of the plain they are frequently seen in railway and road cuttings to be lateritized to a depth of 15 feet, and sometimes to 20 or even 30 feet (Pl. III, Fig. 2). In the more hilly and mountainous parts of the country, especially in the north, laterite is not nearly so well developed. The mountain sides are often very steep and bare, and uncovered by vegetation except for a few tufts of grass, and even in the broad valleys opening out on to the plain, and on the northern part of the plain itself, the laterite occurs only as patches of gravel. The conditions in this part of the country are similar in many respects to those of the mountain districts of Mozambique, concerning which Dr. A. Holmes states:[1] "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 around the base of the hills."

The lateritization of the granitic rocks proceeds as follows: the rocks become broken down into small masses by weathering at the surface and by decomposition along joints and the less resistant bands; the decomposition then proceeds inwards from the outer

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[1] "The Lateritic Deposits of Mozambique": GEOL. MAG., 1914, p. 534.

surface of each mass and forms generally a white kaolinized shell, which continually increases in thickness until it involves the whole mass. The white mass gradually breaks up later and becomes increasingly stained on the destruction of the iron-ores and ferromagnesian minerals; it forms finally a great thickness of soft red-brown lateritic clay, almost homogeneous in composition and texture. The uppermost portion of this lateritic clay then forms locally a hard crust of laterite up to several feet in thickness, due to the growth and ultimate coalescence of numerous small ferruginous concretions which gradually appear in it. In some places the concretions give rise only to a coarse laterite gravel.

A similar decomposition of the mica-schists, gneisses, and granites of French Guinea has been described by Professor Lacroix.[1] He includes the kaolinitic decomposition product and the lateritic clay in his "zone of leaching" and the laterite crust in his "zone of concretion". The granites of Mozambique,[2] however, are rarely kaolinized; where they have undergone this mode of alteration, the kaolin does not pass into lateritic clay and laterite, but is capped by a thickness of damp, black soil. The alteration in this case is ascribed to a heavy growth of vegetation.

It can frequently be demonstrated in railway cuttings (Pl. III, Fig. 2) that a great thickness of laterite may be formed from alteration in situ of crystalline rocks, for the forms of the original masses are still in evidence, and so also are the quartz veins which pierced them; such masses are now represented only by faint patches or ghosts, whereas the quartz veins stand out clear and unaltered, showing their original form and foliation. There is a progressive change from the unaltered rock to the laterite crust, the crystalline rocks in this way presenting a marked contrast to the basic rocks (p. 212).

The Pleistocene and Recent beds of the plain become lateritized in a similar manner, and the resultant product is indistinguishable from the laterite formed directly from the crystalline rocks.

Lateritic iron-ores are formed locally where iron is abundant in the country rock, but with the exception of those in the Colony (as distinct from the Protectorate) (see p. 217), they are of no importance.

4. (i) LATERITIZATION OF DETRITAL DEPOSITS.

Detrital deposits are also affected by lateritization changes. The phenomena are apparent in a series of stratified beds, which cover the marine platform encircling the Colony. Other detrital deposits affected are the surface accumulations in valleys and gaps, and talus-slopes resting on the steep seaward flanks of the hills. Phenomena similar to those described below are well exposed along the cliffs of the Bullom Shore and in cuttings along that part

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[1] Op. cit., pp. 36, 80.

[2] Holmes, op. cit., p. 536.

of the railway running between Waterloo and Songo. The deposits of the Bullom Shore range from coarse felspathic sands to almost pure clays. Lateritization is most pronounced in the sands and diminishes in the more argillaceous beds until it is practically non-existent in pure clay. The probable explanation is that the sands allow surface waters to percolate through them more freely, and also that they contain a much higher proportion of iron in the form of grains of magnetite.

The typical laterite exposed along the cliffs and in stream beds is a red-brown to bright red scoriaceous rock, moderately hard, and in the hand specimen coarsely porous; the diameter of the pores is about 0·4 in. The texture of the walls surrounding the pores is usually compact, the surfaces being smooth or rough according to increasing size and number of the sand grains. The laterite locally contains small masses, lenticles, and streaks, rarely exceeding 2 feet in length, of loosely compacted yellow sand, mixtures of sand and magnetite grains cemented into a purple mass, and of clay containing anything from mere iron staining to a very high proportion of hæmatite and limonite. When a small lump of the laterite is exposed to the weather for a long time it acquires a smooth lustrous surface, dark-brown to black in colour. The pores in the laterite often remain of uniform character to a depth of many yards; beyond this depth the porous mass passes into a red compact sand pierced by irregular streaks and pipes cemented by iron oxides.

This porous laterite forms a hard crust about 10 feet thick at the top of the Pleistocene deposits of the platform; it is exposed along the upper part of the cliffs and as huge fallen blocks at their foot.

Origin of the Scoriaceous Laterite.—Lateritization depends largely upon the amount of iron originally contained in the beds subject to the alteration, and also upon the ease with which water can percolate through them. Just as the modern marine sands vary considerably in their degree of fineness and the proportion of iron and silt they contain, so probably did the older deposits now upraised to form the Pleistocene platform.

The sandy deposits offer the best means of observing the changes involved, which were as follows:—

Owing to the breaking down and hydration of the iron by the combined effects of waters and varying temperatures, pale yellow spots were produced in the beds. The material forming the spots hardened into little lumps about the size of a pea; as these lumps grew larger their centres became brown, and then red, possibly as the result of increasing dehydration. Consequently, at any later stage, they possessed concentric colour-zones in red, brown, and yellow. In time the lumps, or concretions, coalesced into irregular nodular masses. These masses finally formed a thick crust and arrested the concretionary processes by causing the waters to flow in definite channels through or over the surface of the crust, instead of percolating through the centre mass. If at this stage the rocks are exposed to the action of erosive agencies, the unaltered sands between the concretions are washed out, and only a coarse red mass remains; this mass tends to become harder and more porous as time goes on. This process is illustrated at any place where cliffs formed of Pleistocene deposits are being eroded by the sea, for the waves continue to cut out the soft sandy beds under the crust until it falls to the foot of the cliffs in large yellow-brown masses. When newly fallen these masses are rubbly and easily broken; soon, however, they commence to harden and the soft material between the concretions is worn away, leaving only the red, porous laterite. When the iron is distributed locally and irregularly it forms ferruginous strings and pipes traversing a mass of partially compacted sand.

In the sandy clays the changes take place more slowly, and the growing ferruginous concretions do not harden until a much later stage in the general alteration is reached. Meantime, the partly altered beds remain uncemented and brightly mottled in purple, red, brown, and yellow. As compared with laterites formed from less clayey beds the concretions in the sandy clay are smaller and the resulting mass less coarsely porous.

The thick beds of white, cream, or grey clays do not alter appreciably, except to acquire irregular films of hæmatite due to the infilling of desiccation cracks. The red and yellow or red and white mottled clays which collect locally in passes and in valleys owe their colouring to the above processes; they do not contain enough iron to produce hard concretions, and consequently they remain plastic while wet, and become hard and compact when dry.

(ii) LATERITIC IRON-ORES.

The detrital laterite passes locally into lateritic iron-ore by increase in the percentage of iron oxide. Such iron-ores are well developed along the inner margin of the coastal plain encircling the Colony, and occur principally in the neighbourhood of Devil Hole, near Waterloo. They were derived originally from the magnetite (titanomagnetite), which is such an important constituent of the norite mass forming the Colony. They were accumulated at an earlier period in the same way as black sands are accumulating on the coast to-day. The sea formerly reached as far as the inner margin of the present plain, and as the streams brought down the products of weathering from the hillsides the grains of iron-ore were deposited principally near the shore, and the lighter minerals, chiefly felspar and weathered ferromagnesian crystals, were carried further out, to build up the plain as now existent. Consequently the beds near the old shore-line contain a higher proportion of iron than those distant from it, and are sufficiently rich locally to rank as iron-ores. The ores have attained their present condition through the oxidation and hydration of a great proportion of the titaniferous magnetite, The grade and structure of the ores vary considerably. The common variety is pisolitic; the cores of the pisoliths are black and deep red, the enclosing part red, and the interstices between the pisoliths are more or less filled with limonite. Another variety is finely mottled in purple, red, and yellow, and shows only a slight development of the pisolitic structure. The richest ores are made up of nodules or small masses of almost unaltered titaniferous magnetite, whereas the poorest ores are concretionary and contain only a low percentage of iron, chiefly in the form of thin limonitic coatings to the concretions.

A fragment of ore exposed on the surface of the ground weathers into a rounded nodule, and assumes a smooth polished ferruginous skin of a dark-brown colour.

The Devil Hole ores form a belt 400 to 500 yards wide, running parallel with the foot of the hills; the belt has been traced for three miles, and probably extends over a much greater distance. Several small shafts and a trench 15 yards long were excavated in the deposit with the help of explosives; the sections showed soil and subsoil up to 15 inches in thickness, passing downwards into a rubble containing large and small coarsely porous lumps. Underlying the rubble were large masses of a compact ore, which locally assumed an irregular platy structure. The ore was proved to a depth of 8 feet, and it probably continued to a much greater depth; there are thus well over 3,000,000 tons of ore indicated in this deposit. The deposit runs parallel with the Sierra Leone Government Railway, and is practically adjacent to it; moreover, since it is separated from the mouth of the Bunce River only by a narrow strip of the plain, about a quarter of a mile wide, the ore could be shipped directly at very little cost.

Mr. G. F. Scott Elliott [1] gives the following analysis of a sample of the ore from this district ("the hills behind Sierra Leone"):—

Protoxide of iron	70·62
Peroxide of iron	11·10
Titanic peroxide	14·10
Chromium peroxide	·15
Manganese peroxide	·20
Silica and silicates	10·31
Sulphur	·03
Phosphorus	·04
Lime	·02
Moisture	1·25
Oxygen and loss	2·18

Other analyses [2] of representative samples show that the amount of titanium they contain varies from 3 to 20 per cent, and since, under present conditions, steel cannot be made at a profit from

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[1] Col. Rep. Misc., No. 3 (Sierra Leone), 1893, p. 6.

[2] Kindly made for the Geological Survey by the Wigan Coal and Iron Company, Ltd.

iron-ores containing more than 3 per cent of titanium, there is no immediate prospect of a demand for these ores.

5. LATERITIZATION AS A FACTOR IN CAVE PRODUCTION.

There are many small caves and subterranean watercourses in the colony, due to the removal of unconsolidated sand from beneath a hard crust of laterite, and streams are known suddenly to appear and disappear, much as they do in limestone districts. Hart's Cave near York, and Devil Hole, near Waterloo, are the best-known instances of these phenomena.

Hart's Cave opens out on to the foreshore and runs back into the cliff for about 100 yards; it is about 35 feet in average width, and some 12 feet high, and owes its origin to a stream which runs its whole length and issues at its mouth. The stream has washed out the soft sand filling a trough in the norite, which outcrops along the foreshore, and left the hard, lateritic crust above standing as a roof.

The entrance is relatively small, and has been artificially reduced by a stone wall built half-way across it.

Devil Hole is a swallow-hole a few hundred yards to the north-east of the flag station of that name. It is a more or less cylindrical pipe in the laterite, 25 feet deep and 6 to 8 feet wide, and it opens out on the coastal plain at a height of nearly 100 feet O.D. Leading away in different directions from the bottom of the pipe are several low passages, which were dry when examined early in the dry season.

Caves are sometimes formed in the lateritized talus slopes of the steep seaward flanks of the mountains; the exposed outer layers harden into a crust strong enough to support itself when those below subside or are washed out. When the crust itself collapses wide-open caverns are formed, like those seen on the hill-side above the railway station at Waterloo, and that in the Babadori Valley, below Hill Station.

6. SUMMARY.

1. Lateritization has been found to affect a variety of rocks in Sierra Leone, including norite, granitic rocks, and detrital deposits.

2. The norite of Sierra Leone is not deeply lateritized except in highly jointed areas or in certain bands readily susceptible to the alteration. It yields a gibbsitic laterite. A core of unaltered norite is enclosed in a light-coloured halo ("zone of leaching" of Professor Lacroix), which passes gradually into a red-brown laterite ("zone of concretion"). The transition from core to laterite is a rapid one. The minerals of the norite are attacked in the following order: felspar, diallage, hypersthene, magnetite (titanomagnetite).

3. Norite containing only a small quantity of disseminated magnetite is less readily lateritized than norite containing a moderate amount. Where, however, the norite includes an unusually high proportion, as in the streaks of magnetite, lateritization proceeds very slowly.

4. The granitic rocks of the Protectorate are frequently lateritized to a depth of 15 feet, and sometimes even to 30 feet. Nevertheless laterite is only slightly developed in the inselberg mountain districts of the northern part of the country. Lateritization of granitic rocks proceeds as follows: the rocks decompose into a white kaolinitic product, which passes into brown lateritic clay ("zone of leaching"); this lateritic clay then develops into laterite ("zone of concretion"). There is a progressive change from the unaltered rock to the laterite crust, the granitic rocks in this respect presenting a marked contrast to the basic rocks.

5. Lateritization affects detrital deposits also, particularly the Pleistocene sands and clays of the coastal plain. The phenomenon is most pronounced in the felspathic sands and diminishes in the more argillaceous beds until it is practically non-existent in pure clay. The typical lateritite is a red-brown scoriaceous rock, moderately hard, and in the hand specimen coarsely porous. It forms a crust about 10 feet thick at the top of the Pleistocene beds. This lateritite is indistinguishable from the laterite derived from other rocks.

6. The scoriaceous laterite (lateritite) was produced by the growth and ultimate coalescence of numerous small ferruginous concretions, followed by the removal of the soft material between the concretions.

7. The laterite formed from detrital deposits passes locally into lateritic iron-ore by increase in the percentage of iron oxide. Such iron-ores are well developed along the inner margin of the coastal plain encircling the colony, and occur principally in the neighbourhood of Devil Hole, near Waterloo. They were derived originally from the titanomagnetite which enters largely into the composition of the norite, and they are consequently very rich in titanium.

8. Lateritization is frequently an important factor in the production of caves and subterranean channels, owing to the ease with which the unconsolidated material is removed from beneath the thick hard crust of laterite.

In conclusion, I have great pleasure in recording my indebtedness to Professor A. H. Cox, of University College, Cardiff, who kindly made many useful suggestions during the writing of these notes.

EXPLANATION OF PLATE III.

Fig. 1.—Lateritized norite, in railway cutting, Wilberforce, Sierra Leone. The photograph illustrates a late stage in the lateritization of two blocks of norite. Each block is now represented only by a core of unaltered norite enclosed in concentric shells of laterite. The original upper surface of the right-hand block is indicated by the position of the hammer.

Fig. 2.—Residual laterite derived from granite, railway cutting near Baoma, Sierra Leone. The unaltered granite forms a ridge which traverses the cutting obliquely from right to left.

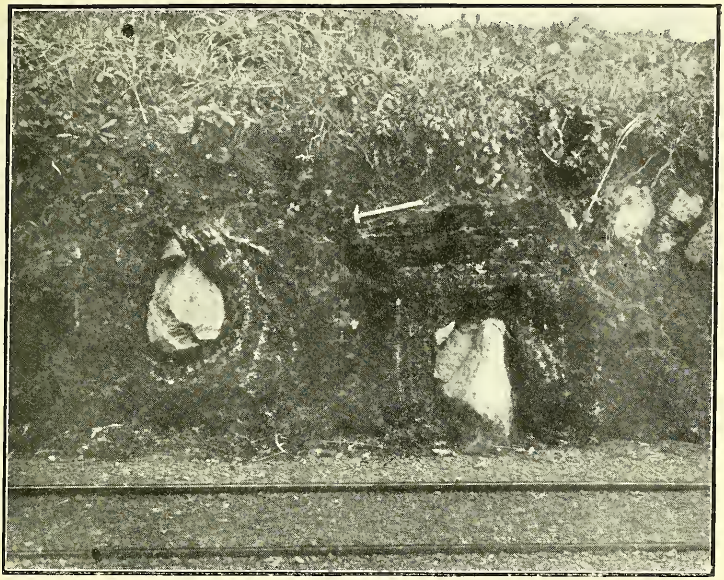

FIG. 1.—Lateritized norite, Wilberforce, Sierra Leone.

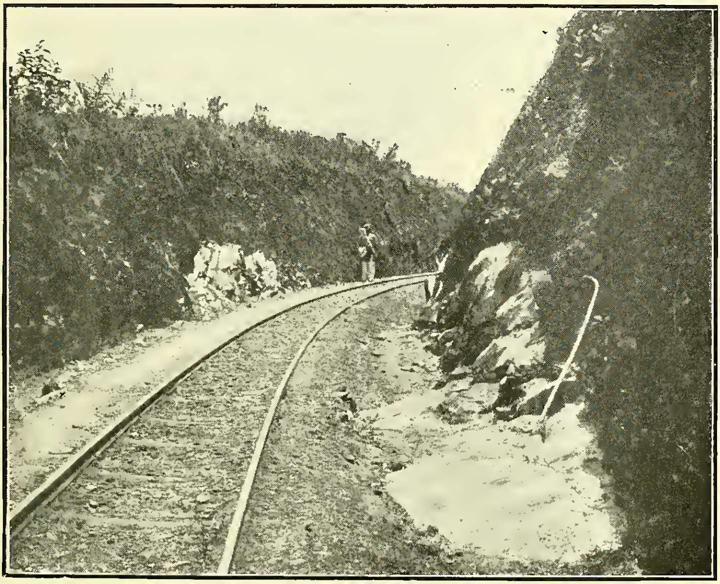

Photo. F. Dixey.

FIG. 2.—Residual laterite derived from granite, Baoma, Sierra Leone.

The Geological Age of the Earliest Palaeolithic Flint Implements.

By J. Reid Moir.

THE investigations which I have carried out in the Ipswich district of Suffolk, and certain discoveries (to be described shortly) made during the past year at Mundesley, Norfolk, have impressed upon my mind the possibility that the ordinary platessiform and batiform palæolithic flint implements found usually in river terrace gravels are older geologically than has been generally imagined. This, however, is not altogether an original opinion, as the late Professor James Geikie, F.R.S.,[1] the late Mr. S. B. J. Skertchly,[2] and Mr. A. S. Kennard,[3] basing their views upon evidence other than that upon which I rely, arrived at a similar conclusion. As is well known, it was stated authoritatively many years ago that our English river-valleys containing implementiferous gravel beds were cut through, and are therefore later than the Chalky Boulder-clay.[4]

Now, however, a closer examination, or access to sections not visible years ago, has demonstrated that in the case of the main river-valleys of Suffolk this dictum no longer holds good.[5] Further, it would appear hardly justifiable to assume that because a gravel bed can be shown to have been laid down after the deposition of the Chalky Boulder-clay, the flint implements contained in such a gravel, which are often considerably rolled and older than the bed in which they occur, are, necessarily, to be referred to post-Chalky Boulder-clay times.

Again, for many years past Continental archæologists and geologists have recognized that the various races of palæolithic man lived in mild epochs intervening between the different glacial episodes, and, as England during the greater part of the palæolithic period was joined to the Continent and experienced probably similar vicissitudes of climate, it would seem unlikely that all the English palæolithic artefacts are post-Glacial.

The discoveries to which I have referred have led me to propose the following table, showing the various prehistoric flint cultures and their relationship to the glacial deposits of East Anglia. I have also ventured to attempt a correlation of these East Anglian glacial deposits with those recognized upon the Continent by Professor Albrecht Penck.[6] But this is, at present, a tentative correlation,

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[1] *The Great Ice Age*, pp. 520–46.

[2] *The Geology of the Fenland* (Mem. Geol. Surv. Great Britain).

[3] "The Pleistocene Succession in England": Proc. P.S.E.A., vol. ii, pt. ii, pp. 249–67.

[4] Sir J. Prestwich, Phil. Trans., vol. cl, 1869, p. 305.

[5] Boswell, "The Age of the Suffolk Valleys": Quart. Journ. Geol. Soc., vol. lxix, pp. 581–620.

[6] *Die Alpen im Eiszeitalter.*

and, further, I would wish it to be clearly understood that the views expressed in this note are based solely upon discoveries made in the Ipswich district, an area with which I am intimately familiar.

NEOLITHIC.—On the high ground near Ipswich a flint arrow-head was found in the surface soil.[1] In the bottom of the Gipping Valley a chipped and polished flint axe has been discovered recently under 3 to 4 feet of peat surface soil. (*Man*, in course of publication.)

UPPER PALÆOLITHIC: *Magdalenian.*—No certain traces found, unless a floor in Ivry Street, Ipswich, buried under 2 or 3 feet of stoneless snuff-coloured sand, can be referred to this cultural phase. This floor is situated upon the plateau.[2]

Solutrian.—A patinated and rolled early Solutrian flint blade was found in gravel at the site of the Ipswich Electric Power Station, situated in the bottom of the Gipping Valley.[3]

Two Early Solutrian blades were found in hill-wash overlying the Aurignacian floor in Messrs. Bolton & Co.'s brickfield, Henley Road, Ipswich.[4] This hill-wash was probably laid down during a period of low temperature, and may perhaps be regarded as the equivalent, on the high ground, of the river-gravel in the Gipping Valley containing a Solutrian blade. The period of low temperature responsible for these depositions may have been that known upon the Continent as the *Würm.*

AURIGNACIAN.—A well-marked floor, containing Aurignacian flint implements, covered by the above-mentioned hill-wash, and resting upon loamy sand in Messrs. Bolton & Co.'s brickfield, Ipswich.[5]

LOWER PALÆOLITHIC: *Upper Mousterian.*—A well-marked floor, containing Upper Mousterian flint implements, generally covered by peat or loamy sand, *and resting sometimes upon Chalky Boulder-clay* in Messrs. Bolton & Co.'s brickfield, Ipswich.[6]

? *Middle Mousterian.*—A floor with ? Middle Mousterian flint implements and abundant remains of reindeer, occurring in loam, and under 4 feet of alluvium and 8 feet of gravel (the deposit containing the Early Solutrian blade above mentioned) at the site of the Electric Power Station, Constantine Road, Ipswich.[7]

Lower Mousterian.—Flint implements found in Chalky Boulder-clay at Bolton & Co.'s brickfield, Ipswich, and Mason's Cement Works, Claydon.[8]

The Chalky Boulder-clay may be referable to the *Riss* glaciation.

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[1] Moir, Journ. Roy. Anthr. Inst., vol. xlvii, 1917, pp. 406–7.

[2] Moir, Proc. P.S.E.A., vol. i, pt. iv, pp. 475–9.

[3] Hancox, Proc. Suff. Inst. Arch. and Nat. Hist., vol. xi, pt. i and pt. ii, fig. 4.

[4] Moir, Journ. Roy. Anthr. Inst., vol. xlvii, 1917, pp. 405–6.

[5] Ibid., pp. 367–412.

[6] Ibid.

[7] Moir, *Man*, vol. xviii, No. 7, July, 1918.

[8] Moir, Proc. Suff. Inst. Arch. and Nat. Hist., vol. xvi, pt. ii, pp. 98–134.

Acheulean.—Late Acheulean flint implements found by Miss N. F. Layard in a silted-up channel in the plateau at Foxhall Road, Ipswich.[1] One such specimen (now preserved in the British Museum, Bloomsbury), recovered by me on the eastern side of the channel, occurred upon sand overlain by contorted material classed by Boswell as " Upper Glacial ".[2]

Chellian.—Small *derived* specimens of Chellian, platessiform implements were found in the Middle Glacial Gravel at Bolton and Co.'s brickfield, Ipswich.[3]

This gravel may perhaps be regarded as of *Mindel-Riss* interglacial age.

The discoveries made upon the Mundesley coast, and further researches carried out this year at Cromer, tend to show that the glacial gravels overlying the Till contain derived Chellian flint implements, and from the finding of certain flakes, etc., in the Cromer Forest Bed it is suggested that this deposit is the real Chellian horizon. The Till and associated beds may possibly represent the depositions of the *Mindel* glaciation. The Chellian implements may therefore be of *Günz-Mindel* interglacial age.

PRE-PALÆOLITHIC.—The flint implements found in the detritus-bed beneath the Red Crag of Suffolk.[4] These specimens, which I regard as of pre-Chellian types, are frequently striated. It is possible that these striæ were imposed during the *Günz* glaciation (the earliest glacial epoch recognized by Penck), and the large block of dark-red porphyry, " weighing about a quarter of a ton," seen by Prestwich to be resting upon the London Clay at the base of the Coralline Crag at Sutton, near Woodbridge,[5] may have been transported by the ice of this glacial episode.

The very primitive edge-trimmed stones, known as " eoliths ", occur as deeply iron-stained and rolled derivatives in the Middle Glacial Gravel in Messrs. Bolton & Co.'s brickfield, Ipswich.[6]

These specimens are regarded as representing the earliest efforts of man to fashion flints, and as being the precursors of the Sub-Red Crag artefacts.[7]

It is also believed that the Sub-Red Crag rostro-carinate flint implements developed into the earliest platessiform and batiform Chellian implements.[8]

The discovery of Acheulean flint implements at Hoxne[9] and at Foxhall Road, Ipswich,[10] occurring in deposits resting upon Boulder-

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[1] Journ. Roy. Anthr. Inst., vol. xxxiii, 1903.

[2] Proc. Geol. Assoc., vol. xxv, pt. iii, p. 136.

[3] Moir, Journ. Roy. Anthr. Inst., vol. xlix, 1919, pp. 74–93.

[4] Moir, Proc. Prehis. Soc. East Anglia, vol. i, pt. i, pp. 17–43, and other papers.

[5] *The Structure of the Crag-beds*, London, 1871, p. 117.

[6] Moir, Proc. P.S.E.A., vol. i, pt. iii, pp. 307–19.

[7] Moir, *Pre-palæolithic Man*, pp. 21–34. Harrison, Ipswich.

[8] Moir, *Phil. Trans.*, B, 1919, p. 209.

[9] Brit. Assoc. Report, 1896, p. 12.

[10] Journ. Roy. Anthr. Inst., vol. xxxiii, 1903.

clay, are of importance in this inquiry (it seems that there are two glacial deposits at the latter place, one above the palæolithic horizon and one below it), and it is suggested that, at both these places, occur patches of a once widespread sheet of glacial clay older than what is known as the Chalky Boulder-clay, and perhaps referable to the *Mindel* glaciation. The well-known section at High Lodge, Mildenhall, where a Mousterian brick-earth interdigitates with a mass of Chalky Boulder-clay,[1] represents probably a remnant of the Mousterian deposits, many of which were ploughed up by the ice and furnished the implements of this culture found in the Boulder-clay.

Professor J. E. Marr, F.R.S., who has visited Ipswich and seen and examined the evidence at my disposal, permits me to say that he considers a prima facie case has been made out for the above correlation, so far as the deposits of East Anglia are concerned. He considers, however, that the reference of certain deposits to the periods of glaciation upon the Continent requires further investigation. With this conclusion I am in agreement.

On the Occurrence of Picritic Serpentine at Ebbor, near Wells, Somerset.

By Sidney H. Reynolds, M.A., Sc.D., Professor of Geology in the University of Bristol.

In October, 1904, Mr. H. E. Balch, of Wells, forwarded some pieces of " trap " from Ebbor to the late Mr. H. B. Woodward, who handed them to Dr. J. S. Flett for examination. At a slightly later date pieces were given to me by Dr. T. F. Sibly, who was then at work in the Mendips.

It was at once clear that we had here an ultra-basic rock, and Dr. Flett, whose description will be quoted immediately, pointed out the practical identity of the rock with that from Clicker Tor, Menheniot, Cornwall, whence he believed the specimens had been derived. The rock occurred in the form of small pieces, rarely more than 2½ inches long, scattered over quite a limited area about a quarter of a mile N.W. of Wookey Hole and due south of Lammas Wood. The very great majority were found in a field due south of Lammas Wood, a few pieces were found in the next field to the west, and one in the adjacent field to the east. The area lies slightly below the 400 ft. contour-line. The pieces are all fairly angular and comparatively little weathered. Probably over 200 pieces of the rock have been found here from time to time; on December 18, 1906, I myself found twenty-one pieces scattered over a small space in the central part of the eastern third of the chief field. I have found others on subsequent occasions, but for some years now have not been able to find any more. Mr. Balch, however, reports

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[1] Sturge, Proc. P.S.E.A., vol. i, pt. i, pp. 43–105.

finding a piece in 1914. No pieces have been detected in any of the neighbouring walls, and the neighbourhood has been so carefully examined that if the rock occurred in situ it could scarcely fail to have been found.[1]

The country rock forming the fields where the picritic serpentine occurred is the Dolomitic Conglomerate, and another possibility which suggested itself was that we might be dealing with a pre-Triassic intrusion, and that the pieces found were pebbles in the Dolomitic Conglomerate.[2] To test this the Dolomitic Conglomerate was exposed by means of trial-holes at a number of points in the principal field, but no fragments of picritic serpentine were ever found.

The only remaining alternative to account for the presence of the rock is that it was brought from a distance and presumably from Menheniot. The suggestion that it was brought by human agency may, I think, be dismissed. Another explanation, and perhaps the most probable, was suggested in conversation by Professor Bonney, viz. that the pieces were derived from an ice-borne boulder.

The acceptance of this theory implies great submergence of the South of England, as the pieces occur at a height of 375–85 feet above Ordnance datum. It may, however, be recalled that Dr. J. V. Elsden[3] in 1887 described a granite boulder from Kithurst, in Sussex, which was found at the 600 ft. contour-line at the summit of the Chalk escarpment. The transport of material probably from Cornwall, which this theory involves, is also perhaps a difficulty, as the great majority of the foreign boulders on the south coast of England, which appear to owe their presence to floating ice, seem to have come from the north-east.[4] On the other hand the erratic blocks collected by Mr. Clement Reid from the Pleistocene deposits of Selsey, included rocks which reminded Professor Bonney[5] of types met with in Brittany, and one specimen was probably of Cornish origin. It is not, however, necessary to assume that such a submergence took place in Pleistocene times; the height at which the pieces of picritic serpentine were found is very much that of the platform rising to the 430 ft. level, which has been recognized along much of the southern part of the British Isles, from Ireland, through

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[1] Mr. Balch, however, writes (June 14, 1914): "I am not at all convinced that the ice transport theory can hold. . . . I am strongly inclined to suspect an intrusion, small and so far not detected."

[2] This is the explanation suggested in a paper by the author read before the British Association at York in 1906 (Trans. of Section C, p. 581). There is also a brief account of the rock in the author's *Geological Excursion Handbook for the Bristol District*, 1912, p. 119. Mr. Balch shows the area in which the picritic serpentine was found in his *Wookey Hole*, pl. vi.

[3] Quart. Journ. Geol. Soc., vol. xliii, 1887, pp. 649–51.

[4] R. A. C. Godwin-Austen, Quart. Journ. Geol. Soc., vol. vi, 1850, p. 88. J. Prestwich, ibid., vol. xlviii, 1892, pp. 295–8. G. Barrow, *The Geology of the Isles of Scilly* (Mem. Geol. Surv., Sheets 357 and 360), p. 24.

[5] Quart. Journ. Geol. Soc., vol. xlviii, 1892, p. 351.

South Wales, to Devon and Cornwall, and which is generally attributed to the work of the Pliocene sea.[1] The suggestion is therefore made that the picritic serpentine is derived from a boulder dropped from an iceberg floating in the Pliocene sea.

Dr. J. S. Flett's description of the specimens sent to Mr. H. B. Woodward by Mr. Balch is as follows:—

"Augite Picrite, passing into serpentine."

"The hand specimens have a dark green colour and a smooth fracture, with slightly unctuous feel. The microscopic section shows that the rock consists mostly of rounded grains of olivine, decomposing into aggregates of yellow and green serpentine. These are partly embedded in or surrounded by irregular plates of pale brown augite, evidently of later formation than the olivine, on which it is to some extent moulded. Olivine forms at least one-half of the rock, and hence typical lustre mottling is not developed. A little secondary hornblende is also present. In all its features this rock is identical with the picrite of Clicker Tor, Menheniot, Cornwall, from which it has probably been derived."

The silica percentage as determined by Mr. E. M. Lane in 1906 in the chemical laboratory of University College, Bristol, is 30·66. The specific gravity as determined both by Mr. E. M. Lane and Mr. F. S. Wallis is 2·71, the relative lowness being no doubt attributable to the weathered character of the rock.

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[1] See Barrow, Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 384.

REVIEWS.

THE PRINCIPLES OF ECONOMIC GEOLOGY. By WILLIAM HARVEY EMMONS, Ph.D. pp. xviii + 606, with 210 text-figures. New York: McGraw-Hill Book Company, Inc. London: Hill Publishing Co., Ltd. 1918. Price 24*s*. net.

IN this book the author presents a perspective of the present position of the scientific knowledge of metalliferous and non-metalliferous mineral deposits, with the exception of fuels and oil. However, the amount of space devoted to the non-metalliferous deposits amount to only about 70 pages out of 600, and it is to all intents and purposes a textbook of the geology of metalliferous mining. The first twenty-one chapters of 290 pages are devoted to a discussion of general principles, while the rest of the book is occupied by descriptions of actual occurrences, classified under the headings of the various metals or non-metals.

This is perhaps scarcely the place to discuss the general question of the rival classifications of ore-deposits, genetic or chemical; nevertheless it may be allowable to point out that the method here adopted presents many practical advantages, and certainly makes reference easy. A genetic classification, such as has been adopted in most of the larger German books, is perhaps more strictly scientific, but it is certainly confusing to the learner, since it brings together a whole lot of deposits which have little in common from the point of view of the miner and metallurgist, however similar their origin may be. On the other hand, an arrangement by metals groups in one chapter or section deposits that may have been formed in a great variety of ways, and a special difficulty presents itself in the case of ores worked for more than one metal. It is clear that an ideal classification has not yet been evolved, and from the nature of the subject it probably never will be. The whole matter is a question of the balancing of advantages and drawbacks, and in our opinion Professor Emmons has acted wisely in choosing as he has done.

The earlier chapters afford an admirable discussion of the general geological, mineralogical, chemical, and physical principles underlying the formation of workable mineral deposits. The metalliferous deposits are classified under eight headings, as magmatic segregations, pegmatite deposits, contact-metamorphic deposits, deposits of the deep vein zone, deposits formed at moderate depths by hot solutions, deposits formed at shallow depths by hot solutions, deposits formed at moderate and shallow depths by cold and meteoric solutions, and sedimentary deposits. This subdivision seems somewhat elaborate; it is very doubtful, for example, whether any real distinction can be drawn between pegmatites and veins of the deep zone, and it is well known that certain pegmatite dykes can be followed laterally or vertically into ordinary quartz veins, as indeed is explicitly admitted by the author, who also recognizes clearly that most of his groups grade into each other by imperceptible transitions. The whole question really hinges on the extent to which the circulation of meteoric waters has taken part in the processes of ore-formation, and as is generally known more importance is assigned to this agency in America than in Europe, perhaps mainly owing to the influence of Pošepný. In many American writings there are still strong evidences of the survival of the lateral secretion theory of Sandberger, and indeed something very like it is generally put forward in explanation of the origin of the lead-zinc deposits of Missouri and Kansas. Still more common is the conception of vein-formation by downward movement of meteoric waters into a region of high temperature where metals are dissolved and carried to a higher level by subsequent rise of the heated solutions. Acceptance of this theory is rendered difficult, amongst other evidence, by the fact that many deep mines are dry in their lower levels. The common occurrence of distinct ore-zones around and above intrusions is also difficult to explain on this hypothesis. These questions are discussed at length by Professor Emmons, who gives a most interesting summary of the divergent views on the subject, with a statement of the arguments for and against each of them.

A whole chapter is devoted to a detailed discussion of the superficial alteration and secondary enrichment of ore-deposits, so important from the practical point of view. Although the general underlying principles are well understood, certain points are still in need of explanation; it is still somewhat uncertain whether chalcocite and some other sulphides are ever truly primary, although the balance of evidence from observation suggests that they are. The whole process of oxidation, solution, and reprecipitation obviously depends on the chemical and physical conditions prevailing in the different regions of the ground-water, but the chemical changes involved are very complex and not yet fully elucidated.

The second and larger part of the book consists of descriptions of actual occurrences of minerals of economic value. These are very clear and effective, but it is perhaps admissible to remark that in this section a certain want of balance is shown. Descriptions are given of many American deposits of little economic value and still less scientific interest, while the important mining regions of other parts of the world receive scant attention. It may be suggested with all due deference that the object in view would have been better attained by treatment of a smaller number of examples, culled from all parts of the world and selected so as to illustrate general principles. Thus the student of economic geology, for whom the book is primarily intended, would acquire a better sense of proportion and learn to appreciate more fully the scientific and commercial value of certain highly important types of mineral deposit which do not occur in North America.

R. H. Rastall.

A REVIEW OF THE REPTILIAN FAUNA OF THE KARROO SYSTEM OF SOUTH AFRICA. By S. H. HAUGHTON. Trans. Geol. Soc. South Africa, vol. xxii, 1919, pp. 1–25, with 4 figs.

MANY of the reptiles described in this paper are of unusual interest, as they are forms identical with or closely similar to the progenitors of the mammals. The general nature of the reptilian fauna in each of the principal series of the Karroo system (namely the Dwyka, Ecca, Beaufort, and Stormberg) is described, and then the relationships of the Karroo reptiles are discussed. The author traces the changes which occur as we pass from the primitive *Pareiasaurus* to the much more mammal-like animals represented by the Theriodonta. In the former the bones of the back of the mandible are well developed, but as we pass upwards we find a gradual reduction in the bones of this region and a corresponding enlargement of the dentary, which in mammals comes to articulate with the squamosal. Meanwhile the palatal portions of the premaxilla and maxilla become enlarged, and each bone meets its neighbour in the middle line, just as occurs in mammals. Furthermore, it is shown that the changes which took place were not always in the direction of increased specialization, since the teeth in *Endothiodon* are all molar, the incisors and canines having been lost, while in *Prodicynodon* and *Diaelurodon* the incisors alone have been lost. There can be no doubt, however, that all these genera are derived from forms which had a typical heterodont dentition, like mammals. The author believes that the "law of irreversible evolution", whereby an organ once lost can never be regained, though it may be replaced functionally by another organ, is a principle of universal application, but why the possibility of reversion followed by persistence due to survival value should be ruled out is difficult to see. Indeed, the results of modern breeding experiments are not always in conformity with this so-called "law" or "principle".

The paper is of great interest to the student of evolutionism.

F. H. A. M.

NOTES ON THE PLEISTOCENE FOSSILS OBTAINED FROM RANCHO LA BREA ASPHALT PITS. Los Angeles County Museum of History, Science, and Art, Department of Natural Sciences, Miscellaneous Publications, No. 2. pp. 35, with 22 figures. Los Angeles, 1918.

THIS paper contains figures and descriptions of various fossil mammals of interest: of these the skeleton of the Imperial Elephant, which was 3½ feet higher than any known modern specimen of *Elephas*, and that of the prehistoric Camel, an animal which, like the horse, originated in North America and then became extinct there, are specially noteworthy.

The skeletons of the animals which were trapped in the asphalt beds of Rancho la Brea and preserved in the oil are very remarkable, and it is interesting to note that the same process is going on at the present day in the excavated pits, where rabbits and other animals stumble into the pools of oil and become engulfed. A photograph is reproduced of a jack-rabbit entrapped in this way.

F. H. A. M.

IMPERIAL SOURCES OF POTASH.

(1) SOURCES OF INDUSTRIAL POTASH IN WESTERN AUSTRALIA. By E. S. SIMPSON. Geol. Surv. W.A. Bull. No. 77, 1919. (2) POTASH RECOVERY AT CEMENT PLANTS. By A. W. G. WILSON. Canada, Dept. of Mines, Bull. No. 29, 1919. (3) THE POTASH SALTS OF THE PUNJAB SALT RANGE AND KOHAT; and SUGGESTIONS REGARDING THE ORIGIN AND HISTORY OF THE ROCK-SALT DEPOSITS OF THE PUNJAB AND KOHAT By MURRAY STUART. Rec. Geol. Surv. India, vol. l, pt. i, 1919.

THE acute shortage of potash which made itself felt during the War stimulated a search for new sources throughout the Empire, and in the three publications cited above the results of some of the investigations then begun are now made public.

1. In the Western Australian Bulletin all the possible sources are fully discussed and methods of treatment suggested. It is found that although immense quantities of wood-ashes are available, the content of potash is in general so extraordinarily small that they are useless except as a local fertilizer. Among potash-bearing minerals the state resources of microcline, glauconite, jarosite, $KFe_3(SO_4)_2 . 3H_2O$, and alunite are described, and it is shown that, if necessary, very considerable supplies could be obtained. It is almost needless to say, however, that the inducement to develop such deposits has now vanished. A detailed account of the alunite deposits of Kanowna is given by T. Blatchford, and the results of an examination of seaweeds for potash and iodine made by I. H. Boas are also set forth.

2. Dr. Wilson has written a valuable summary of the problems, scientific and commercial, associated with the recovery of potash as a by-product in the Canadian Cement industry. Equipment for preventing the escape of flue-dust has already been installed in nineteen cement plants, and of these seventeen were erected with the deliberate purpose of recovering potash. The quantity of potassium salts carried out with the flue-dust varies in ordinary practice from 2 to 7 lb. per barrel (350 lb.) of cement. As the cement plants average an individual output exceeding 3,000 barrels per day, it is clear that thousands of tons of potash are saved annually, and a serious nuisance—due to the escape of dust—considerably abated.

3. A re-examination of the Indian potash deposits was undertaken by Dr. Stuart during the seasons 1915–17. It was found that the potash-salts occur in discontinuous lenticles and irregular foliæ, and that no continuous bed is likely to be discovered in

the Salt Range. "Where the foliation is of the nature of banding, bands of potash may persist for some little distance, but even then they will probably thicken and thin throughout their length. The prospects of obtaining potash in the Salt Range are, therefore, not promising, and it is not likely to be worked profitably except as a by-product of salt-mining." In Kohat potash has been detected in water dripping from a deposit in one locality only, and there it is condemned by its inaccessible situation.

While carrying out his investigation of the economic value of the potash deposits, Dr. Stuart made a number of observations on the saline deposits as a whole, and these he has interpreted and embodied in a most valuable paper on their origin and history. Briefly, it is suggested that the rock-salt of Kohat and the Punjab belongs to one great salt formation, and that the differences in character of the salt exposed from place to place are due to the successive exposure of different zones. The Kohat salt contains calcium sulphate and belongs to one of the lowest zones. Various transition zones are represented, until at Khewra salt which may have belonged to the kieserite- or carnallite-zone is encountered. It is impossible to make a complete analogy between the Stassfurt sequence and that of the Indian deposits, because the latter have been metamorphosed. The existing dip and strike of the saline bands are probably not those of stratification, but represent a foliation in a new and different direction. The patchiness and lenticular form of the potash-bands receive an adequate explanation, and the many puzzling phenomena of sequence and structure are fully accounted for if Dr. Stuart's views are correct. In the German and Alsacian deposits, when potash is once known at any horizon, it can be predicted with certainty over a wide area, but in India "no assertion can be made as to where a lenticle of potash will occur, or as to its dimensions or shape when located". The prospects of obtaining potash from the Salt Range are therefore, unfortunately, far from promising.

ARTHUR HOLMES.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

February 6, 1920.

The President, Mr. J. F. N. Green, delivered an address entitled "The Geological Structure of the Lake District".

General disposition.

The Devonian concertina-folding. Manner in which it affects various rocks. Cleavage. Passage in the main volcanic area from zone of flow in the east to zone of fracture in the west, with concomitant disappearance of folds and development of thrusts. Continuation of the Devoke Water thrusts. The anticlinorium.

Ordovician folding. Simple character. Its importance and main lines.

Interference of the two systems.

Post-Carboniferous movements. The Wastwater fault. Consideration of the effects of faults in highly folded strata. Question of tear-faults.

March 5, 1920.—The President, Mr. W. Whitaker, F.R.S., in the chair.

"The Geology of the Cardiff District, with special reference to the Easter Excursion." By Professor A. Hubert Cox, M.Sc., Ph.D., F.G.S.

Geological history of the district. The general succession and structure. Continued instability and proximity to shore-lines. Effects thereof on the character and distribution of the Palæozoic deposits. The Armorican folding. The Coalfield Syncline and the Cardiff Anticline. The pre-Triassic surface. The Mesozoic unconformity and overlap. Great lateral variation of the Mesozoic rocks. The drainage system and recent deposits. Main scenic features.

"Supplementary Notes on Shooters Hill." By A. L. Leach, F.G.S.

I.—A section in London Clay.

II.—The Minerals of the Shooters Hill Gravel. Results of an examination by Mr. G. Macdonald Davies, M.Sc., F.G.S.

March 26, 1920.—The President, Mr. W. Whitaker, F.R.S., in the chair.

"The Geography and Geology of N.E. France and adjoining areas, with special reference to the War Zone of the Western Front." By Evan W. Small, M.A., B.Sc., F.G.S.

General features of the structural geography of France. The *massif-central* and its historical influences: the regions of the Langue d'oc and the Langue d'oil. The pre-Permian Armorican and Variscan highlands. The young folded mountains of the Alps and Pyrenees. The belted relief of N.E. France. The Cotswold–Langres syncline. Relation of structure and form in upland belts. The concentric scarps as natural defences. The geology of the Vosges and the Faucilles Mountains. The folded Jura and the tabular Jura. The Oligocene trough valley of the Rhine. The eastern frontiers of France in 1812 and 1914. The chain of fortresses. The mineral resources of Alsace-Lorraine. The Sarre coal-field. The Ardennes and beyond. The gorges of the Meuse and Moselle. The porphyroids of the Meuse Valley. Some examples of river capture. The Eocene lowlands of Flanders. The Chalk uplands of Normandy, Picardy, and Artois. The Jurassic inliers of the Boulonnais and the

Pays de Bray. The region round Paris. The battlefields of the Marne. The Aisne tablelands and the Chemin des Dames. A digression on Laon and some other French cathedrals. The battle fronts in Champagne and Argonne. The Côtes de Meuse, the Woëvre, and the St. Mihiel salient. Summary and conclusion.

Institution of Mining and Metallurgy.

March 18, 1920.—The President, Mr. H. K. Picard, in the chair.

"Tin and Tungsten Deposits: The Economic Significance of their Relative Temperatures of Formation." By W. R. Jones.

The tin and tungsten deposits of the world, occurring in situ, can be classified according to their mode of occurrence into five classes: I. Segregation Deposits; II. Contact-metamorphic Deposits; III. Pegmatoid Deposits (which include deposits in minor igneous intrusions, such as pegmatites, aplites, quartz-porphyries, and rhyolites); IV. Quartz Vein Deposits; V. Replacement Deposits.

Evidence is adduced to show that the Segregation and Contact-metamorphic Deposits were formed at higher temperatures than were the Pegmatoid Deposits; that the latter were formed at higher temperatures than were the Quartz Vein Deposits; and that the Replacement Deposits, if such exist, were formed at comparatively low temperatures.

The author believes that a study of the relative temperatures of formation of these deposits, and in particular of the Pegmatoid and Quartz Vein Deposits (which together are the source of the bulk of the world's supply of tin and tungsten minerals) will be found helpful in investigating the probable persistence or non-persistence of the ore-bodies in depth.

The world's tin and tungsten deposits have been classified and briefly described, and certain general conclusions are established therefrom. These conclusions appear to support very strongly two hypotheses advanced in this paper, namely, that deposits in which cassiterite and wolframite occur in intimate association were formed in a lower temperature zone than were the bulk of the tin deposits free from wolframite, and that cassiterite is a higher-temperature mineral than wolframite.

On the assumption that these two hypotheses are correct, and supported by other evidence bearing on the strength, lateral continuity, and mineralization of the lodes and so forth, the author suggests that some of the deposits of Tavoy District, Burma, where cassiterite and wolframite occur in intimate association, will be found in depth to resemble the tin deposits of parts of Siam, of the Federated Malay States, and of Cornwall.

It is emphasized that this method of investigating the difficult problem of what obtains in depth in a new field is not intended to substitute, but to supplement, any other helpful evidence that may be available.

Mineralogical Society.

March 16, 1920.—Sir William P. Beale, Bart., President, in the chair.

Arthur Russell: "On the occurrence of Cotunnite, Anglesite, Leadhillite, and Galena on fused lead from the wreck of the Fireship *Firebrand*, Falmouth Harbour, Cornwall." The specimens were obtained in 1846 from the wreck of the fireship *Firebrand*, which was burnt in Falmouth Harbour about the year 1780. They were found under the lead pump, most of which appeared to have been melted and mixed with charcoal, and consist of slag-like masses of lead, which has evidently been fused, and upon the surface and interstices of which are numerous well-defined and brilliant crystals of cotunnite and anglesite, and more rarely small crystals of leadhillite and galena. The cotunnite crystals, which are colourless and transparent with brilliant faces, are nearly always elongated in the direction of the a axis, and attain a length of 3 mm. The habit is somewhat variable owing to the very unequal development of the faces. The forms observed were 010, 001, 021, 011, 012, 101, 111, and 112. The anglesite crystals are of rectangular habit, and exhibit the forms 100, 001, 110, 102, 122, and 113. The leadhillite crystals, thin six-sided plates in shape, are of a brown colour and show the forms 101, 201, $\bar{1}01$, $\bar{2}01$, 112, 111, $\bar{1}12$, and $\bar{1}11$. The galena occurs in minute cubo-octahedra. An occurrence of cotunnite formed under almost exactly similar conditions has been described by A. Lacroix. Similar occurrences of lead oxychlorides at Laurium, and of leadhillite in Roman slags from the Mendip Hills, were referred to.—W. Campbell Smith: "Riebeckite-rhyolite from North Kordofan, Sudan." A rock found by Dr. C. G. Seligman at the base of Jebel Katul, 350 miles south-west of the Bayuda volcanic field was described.—Dr. G. T. Prior: "The Meteoric Iron of Mt. Ayliff, Griqualand East, South Africa." This meteoric iron, found about 1907, is a coarse octahedrite similar in character to Wichita County (Brazos River) and Magura (Arva). On polished and etched surfaces it shows nodules of graphite and triolite, and abundant cohenite crystals arranged parallel to the octahedral bands. It contains about 7 per cent of nickel.

CORRESPONDENCE.

GAULT AND LOWER GREENSAND NEAR LEIGHTON BUZZARD.

Sir,—I know that my colleague, Dr. Kitchin, has always found it difficult to believe that the fossiliferous limestone beneath the Gault at Shenley Hill can be in its original position, and it is well that he and Mr. Pringle should have undertaken an independent investigation of the sections. But I am certain that they have misinterpreted the evidence in supposing that the limestone has been brought below the Gault by Glacial overturn. This is the only point which it concerns me to discuss at present, as the other issues raised in their recent paper in your pages all depend upon it.

With a much wider knowledge of the sections than I possessed in 1903, when the first account of the fossiliferous band was published by the late J. F. Walker and myself (Quart. Journ. Geol. Soc., vol. lix, pp. 234–65), I shall maintain that the description of the sequence and conditions then given was substantially accurate. Ever since that time I have taken the neighbourhood of Leighton Buzzard as my geological playground, revisiting the sections again and again, often several times a year and rarely missing a year, attracted by the fresh features disclosed in the extension of the great sand-pits and in new excavations. Hence, I have now seen the fossiliferous band at one time or another in a practically continuous section over 300 yards in length and 10 to 50 yards in breadth, from Garside's pit on the south to Chance's pit on the north. Yet I have not found in it the slightest trace of intercalated Glacial material or of Glacial disturbance. Moreover, having made a particular study of glacially transported masses in Yorkshire and other places, I am the less likely to have missed such evidence if it had been present. Also, on reference to my notebook, I find that in April, 1914, I saw patches of pale-pink gritty fossiliferous limestone, somewhat decomposed, associated with the breccia-band at the base of the Gault in the Miletree Farm pit (see Fig. 3 of my critics' paper), which lies outside the area of the supposed overturn; and similar material was lately visible in the same position in another section between this pit and Shenley Hill.

All the new features observed since 1903 have helped to confirm my original view of the sequence. Between 1904 and 1906 the easterly workings of the Garside's pit, now abandoned, disclosed new facts which are absolutely irreconcilable with the hypothesis of Glacial inversion. I mentioned some of these, in brief, in my report on the visit of the Geologists' Association to Shenley Hill in 1908 (Proc. Geol. Assoc., vol. xx, pt. vi, p. 475), and dealt similarly with the Grovebury sections (with which we are not at present concerned) in reporting on a later excursion to Leighton Buzzard in 1915 (Proc. Geol. Assoc., vol. xxvi, pt. v, p. 310); and as Dr. Kitchin knows, I have embodied a further description of them in a paper written just before the War and intended for publication at a convenient season. This paper will afford me an opportunity to deal in detail with the arguments of my critics. Meanwhile, it seems advisable that I should state at once my disagreement with their main conclusion, and show reason for believing it to be wrong.

Last year it chanced that I could not conveniently visit the sections, though I should have contrived to do so if I had been aware that my colleagues' investigation was then in progress. However, I have re-examined the pits twice during the past month, and am satisfied that the features with regard to the fossiliferous band have remained without essential change, and that my critics and I are discussing the same facts in this particular.

Dr. Kitchin and Mr. Pringle rely for proof of the inversion almost entirely upon inferences drawn directly or indirectly from the fossils of the limestones and its associated strata. They infer that the fossils in question—certain brachiopods, lamellibranchs, crustacea, and echinoderms—cannot occur in place below the Gault. But if the stratigraphical evidence is convincing, as I believe it is, that at this locality they *do* occur below the Gault, the *a priori* inference loses all validity. I presume that no geologist will claim that our present knowledge of the range of these particular fossils is so perfect that it cannot be extended. In strata so sparingly and sporadically fossiliferous as the upper part of the Lower Greensand, we know as yet very little about the life of the period. Now, the Shenley section, as I believe, has slightly extended our knowledge; and, in the paper of 1903, my co-author and myself offered what I still hold to be a reasonable explanation of the unusual elements of the fauna. Our critics naturally lay stress upon their own side of the argument, and dismiss the admixture of Lower Cretaceous forms as 'derivatives' and as occurring, perhaps, in a limestone similar to the so-called 'Cenomanian' rock, but of different age, and brought into contact with it by the inversion. I hardly need express dissent from these inferences; they merge into the broader question of the supposed Glacial overturn. Let us consider what this hypothesis implies, and how far it runs contrary to probability.

1. The supposed 'Cenomanian' limestone, a gritty rock of peculiar aspect and composition (fully described in our paper of 1903), is unlike any other rock known in the district, and shows every indication of having been formed on the floor on which it now rests. My critics have sought for it above the Gault all along the foot of the Chalk escarpment, and acknowledge that they have sought in vain. They fall back upon an assumption that it may have occurred above the Gault in a vanished tract in the neighbourhood of Shenley Hill, and that it may have remained at the surface there until the hypothetical inversion in Glacial times. Yet it is only a few inches thick, and is for the most part quite fresh and unweathered.

2. In the same way the bed of loose glauconitic greensand, up to 5 feet thick, which I saw below the Gault, surrounding an upstanding crag of iron-grit, in the easterly part of Garside's pit before the working was abandoned in 1906 (see Proc. Geol. Assoc., vol. xx, p. 475), is supposed to have been overturned from the surface; yet it also, though so readily perishable, shows no trace of weathering.

3. The slab of Gault, greensand, and limestone supposed to have been overturned has proved to extend without visible disturbance over an area of not less than 15 acres, and it still has a thickness of about 18 feet in Harris's pit, which, therefore, must be accepted as the minimum for the whole slab before the overturn. Not a trace

of drift has been found beneath the mass. It is supposed to have been sliced off exactly at the base of the Gault, and, like a pancake, to have been tossed over cleanly back into its bed, without breaking and without entangling any extraneous matter. By this overturn, it is assumed that a thin band of limestone originally at the top of the Gault and a similar thin band of limestone and breccia at its base have been everywhere brought directly into contact within a belt never more than 2 feet thick, and usually less, as shown in Fig. 2 of my critics' paper. Glacialists have been accused at times of expecting too much from ice-sheets, but they have never expected such a feat as this.

4. Reason is shown in our paper of 1903 for believing that the thin irregular layer of iron-grit or ironstone which covers the lenticles of limestone, and to which they appear to owe their preservation, was in existence before the deposition of the Gault. The fresh evidence accumulated during my later investigations has, I think, placed this point beyond doubt. It is, of course, fatal to the hypothesis of my critics, and they are compelled to put forward the argument that the ironstone floors have been formed in Post-Glacial times, after the beds had been overturned, though they tacitly admit that the ironstone fragments between the floors are of pre-Upper Gault age, at least.

But I feel that it is really useless to enter into a lengthy verbal debate in this matter; the evidence speaks for itself in the whole section, and I will ask anyone who is doubtful upon it to make a personal examination of what is to be seen, even though the exposures visible at any particular time can hardly be expected to give the cumulative impression which I have received year by year in seeing one section after another. I feel sure that it will be found easier, on the spot, to believe in an extension of the range of the anomalous fossils than to believe that the bed had been brought into its present position through a gigantic inversion by glacial or other agency.

As regards the Gault, for the present I will only say that my colleagues may possibly be right in claiming that the Upper Gault alone is present under Shenley Hill, though there are several factors which call imperatively for a suspension of judgment in this matter, pending further investigation. I may be permitted to point out that in our paper of 1903 we explicitly stated that the Gault exposed at that time contained no discriminative fossils, and that the presence of the Lower Gault was inferred solely on the evidence of the fossils recorded by Jukes-Browne from a neighbouring pit. But whether Upper or Lower Gault, the statement that it is inverted runs counter to so many points of evidence recently considered in the field, that I have no hesitation in rejecting the supposition as unwarranted.

G. W. Lamplugh.

St. Albans.
April 5, 1920.

CRYSTALLIZATION-DIFFERENTIATION.

Sir,—Mr. H. H. Read's acquaintance with modern French literature is evidently thorough, and one is surprised that this acquaintance has not rendered him more apt at simile. He compares my dependence upon crystallization as an explanation of many features of igneous rocks with M. d'Astarac's dependence upon sylphs as an explanation of ordinary happenings. Unfortunately for his comparison, we know that magmas do crystallize, and equally unfortunately for his dependence upon liquid immiscibility we do not know that silicates unmix. Immiscibility is the petrologic sylph.

In fact, immiscibility is a sort of super-sylph. One sees two related and intimately associated rocks, and one remarks that they were evidently formed from a common magma by unmixing. Since nothing is known about unmixing in silicates, one is therefore relieved from the responsibility of any further thought in the matter. However, Mr. Read's last paragraph rouses some hope. He expects that my excessive advocacy of crystallization will lead some one to champion immiscibility. If this some one will analyse immiscibility from a theoretical standpoint, if he will then apply his results to silicate magmas and examine whether associated igneous rocks bear such a relationship to each other in chemical composition, in time and space relations, that they can or cannot be regarded as the result of immiscibility, he will have conferred a boon upon petrologists, whether a succeeding generation shall find his conclusions right or wrong. But no amount of setting up immiscibility as a sylph will advance petrology.

It is possible, of course, that I have overworked crystallization, but no one who has seen the spring break-up in one of our Canadian lakes could doubt that deformation of a crystal mesh must have important consequences in the case of igneous rocks as well. There one sees weakened and honeycombed bodies of ice under impact from other masses, locally compacted into a solid mass with the water squeezed out of the comb, elsewhere stretched, fissured, and traversed by streaks of open water. That more or less related features could develop below ground is not to be questioned.

Though Mr. Read's review is for the most part a series of objections they are nearly always generalities, and are only occasionally specific enough to be answerable. My method of deriving *some*[1] banded rocks by torsion of a crystal mesh would not, as he concludes, give rise to an orientation of the early crystals normal to the bands. It is in the filling of the lenticular spaces that free flow of liquid occurs, and such crystals as would become detached from the walls of the lens during this action would be carried along by the liquid

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[1] I have elsewhere suggested that banded rocks may at times be formed as a result of intrusion of heterogeneous liquid (not immiscible liquids). "Later Stages of the Evolution of the Igneous Rocks": *Journ. Geol.*, Suppl. to vol. xxiii, 1915, p. 30.

and oriented parallel to the banding. The slight amount of rotation of crystals possible in the compacted part of the mesh would not be sufficient to orient them in any particular way. The action would, as a whole, give rise to bands showing flow-structure, therefore, and exhibiting the moderate contrast between bands that is normal in banded gabbro. The occasional ultra-basic bands of extreme contrast could also be developed as a further result, for in the larger lenses of liquid crystal sorting would occur under conditions particularly favourable to the production of monomineralic types.

Though apparently not himself a strong advocate of crystallization differentiation, Mr. Read appears to have some apprehension that the credit for originating certain ideas in that connexion might leak out of the Tight Little Island. He therefore points out that Darwin postulated crystal-settling seventy years ago, and in two places that Barrow postulated mechanical straining thirty years ago. Though Darwin needs no eulogy of mine or Mr. Read's, I too have pointed out Darwin's origination of the idea of crystal-settling,[1] and though I have not referred directly to Barrow's work, I have referred to Harker's discussion of it and similar work.[2] If I may be permitted, I would like to point out to Mr. Read that the assumption of immiscibility also dates back to Darwin's time, and that it is still an assumption—a sylph, if he prefers the term.

N. L. Bowen.

Kingston, Canada.
February 27, 1920.

OBITUARY.

Robert Etheridge (1847–1920).

Mr. Robert Etheridge, the son of the distinguished geologist and palæontologist of that name, died after a short attack of pneumonia at Colo Vale, near Sydney, on January 4, in his 74th year. Etheridge early took up geological work in Australia, as a member of the first Geological Survey of Victoria, under the direction of A. R. C. Selwyn, in the middle sixties. The survey having been disbanded as the result of a political crisis, young Etheridge returned home and was appointed palæontologist to the Geological Survey of Scotland, his father being then palæontologist to the English Survey. When the natural history collections of the nation were removed from Bloomsbury to the new Natural History Museum in the Cromwell Road, the two Etheridges were brought on to the staff of the Geological Department, where the memory still remains of the vigorous actions and language of "R. E. junior". The chief piece of palæontological work accomplished by Etheridge while in this

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[1] N. L. Bowen, "Crystallization Differentiation in Silicate Liquids": *Am. Journ. Sci.*, vol. xxxix, 1915, p. 175.

[2] "Later Stages of the Evolution of the Igneous Rocks": *Journ. Geol.*, Suppl. to vol. xxiii, 1915, p. 14.

position was the valuable Catalogue of the Blastoidea, in which he had the co-operation of P. Herbert Carpenter.

Australia, however, was never far from the thoughts of Etheridge. He compiled a useful bibliography of Australian Geology, and studied fossils sent to him from Queensland by his former Edinburgh colleague, Mr. R. Logan Jack. This eventually resulted in a large work by the two friends on *The Geology and Palæontology of Queensland and New Guinea* (1892). Meanwhile, in 1887, Etheridge returned to Australia as palæontologist to the Geological Survey of New South Wales and to the Australian Museum, Sydney. Here he strenuously worked for the remaining thirty-three years of his life, becoming Director of the Museum in 1895. At the Mines Department he laid the foundation of what is now a fine library, he started the well-known "Records of the Geological Survey", and he published from time to time important memoirs on the fossils of the older rocks. Produced without the facilities enjoyed by palæontologists at home, these writings were warmly welcomed by them, and "it is not too much to say", writes Professor Edgeworth David, "that the classification and correlation of the coalfields, goldfields, artesian water-basins, oilfields, and other mineral deposits of the Commonwealth are based essentially on the work of Mr. Etheridge." At the Australian Museum Etheridge threw himself with his wonted vigour into the arrangement and display of the collections, and introduced the descriptive labelling initiated in the Natural History Departments of the British Museum. He founded the "Records of the Australian Museum", and under his guidance numerous memoirs on the fauna of the continent were published. He also extended the educational services of the museum by popular science lectures and demonstrations to visitors. In this position he was led, as so many others, away from his own science to follow the insistent call of ethnology. Through his efforts a fine series of ethnological exhibits from the Pacific Islands was accumulated, and a magnificent display of native work was installed in the museum galleries.

Etheridge received the Clarke Memorial Medal from the Royal Society of New South Wales in 1895, and the Mueller Memorial Medal from the Australian Association for the Advancement of Science in 1911. His remoteness from the Mother Country and his objection to advertisement were probably the reasons why similar honours were not conferred upon him by Metropolitan societies. The award of the Wollaston Fund by the Council of the Geological Society in 1877 is all that we can trace. His name, however, is widely known, not from the various fossils that have been named after him, but from the Antarctic glacier, the lofty peak on the Kosciusko Plateau, and the Etheridge goldfield in North Queensland. His colleagues will cherish his memory as that of a sound and untiring worker, and a man always ready to help his fellows.[1]

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[1] See additional paragraph on p. 194 written by Mr. R. Bullen Newton.

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EDITORIAL NOTES.

GEOLOGISTS will note with satisfaction that the University of Cambridge on May 19 conferred the honorary degree of Doctor of Letters on the Abbé Henri Breuil, Professor of the Institute of Human Palæontology at Paris. The following speech was delivered by the Public Orator in presenting the Abbé for his degree: "De gentis humanæ originibus multi antiquitus disputaverunt nec adhuc compositæ sunt controversiæ. Utrum simiis oriundi simus an angelis, ingens fuit rixa. Ossibus nonnullis inventis pithecanthropum quidam finxerunt,

> monstrum horrendum, informe, ingens,

cui lumen non datum. Ex contrario hospes noster cavernas speluncasque Gallicas et Hispanas exploravit, proavorum domos nostrorum et picturis plenas invenit, ex quibus patefactum est ante multa annorum millia vel humanissimos fuisse. Ita linea usi sunt et colore, ita vitae studuerunt, ut cervi depicti vel animum cerneres, dum respectat inhians, et crura movet defatigata. Elephanti primigenii dentes et capillos, equi nasum retusum, rhinocerotis lanam, et noverunt et pinxerunt. Abbatem ergo, qui gentem nostram in humanitatem vindicaverit, laeti salutamus.

"Duco ad vos virum admodum reverendum HENRICUM EDWARDUM PROSPERUM BREUIL."

We hear that Abbé Breuil has spent several weeks in visiting the more interesting British localities that have furnished information concerning prehistoric man, and we hope that he may publish an account of his observations in our Islands.

* * * * *

ON February 20, 1920, Mr. R. Bullen Newton retired from the post of Assistant in the Geological Department of the British Museum, after forty years' service. For twelve years, from 1868 to 1880, Mr. Newton was Assistant Naturalist on the Geological Survey, and in the latter year, owing to special qualifications in the curating of fossils, he was transferred to the British Museum as an Assistant in the Geological Department, then under the keepership of Dr. Henry Woodward. He has therefore completed a period of fifty-two years spent in palæontological work. Owing to pressure on our space it is not possible at the moment to give an adequate account of his distinguished career, but we intend to do so at an early date. It must suffice here to say that he has accomplished an enormous amount of sterling work, a full bibliography of his publications, including joint work, running to no less than ninety-five items, and covering investigations in the palæontology of almost all regions of the world where fossils are found. Mr. Bullen Newton has also occupied the positions of President of the Malacological Society of London (1910–12), and of the Conchological Society of Great Britain and Ireland (1913–15), and his special interests have always lain in the direction of the Tertiary and younger formations.

* * * * *

We have received a copy of the Third Annual Report of the Conjoint Board of Scientific Societies, covering its activities for the year 1919. Several of the Committees deal with matters possessing geological interest, such as those on Iron-ores and the Water Power of the Empire. A Committee formed jointly by this Board and the British Association has entered into negotiations with the University of Cambridge and the Imperial College as to the possibility of obtaining funds for the establishment of a Geophysical Institute. The most interesting report, however, is that of the Petrophysical Institute Committee, of which Sir Jethro Teall is chairman and Professor Fearnsides secretary. A full report has been drawn up on the need for a national institute to investigate the conditions of crystallization of minerals and rocks, and advice has been obtained from the Geophysical Institute and the Carnegie Institution at Washington. The Committee is now prepared to approach the Department of Scientific and Industrial Research with a view to the organization of a Petrophysical Institute.

* * * * *

The twelfth annual report of the governing body of the Imperial College of Science and Technology contains much matter of interest, especially a full account of the work of the Department of Geology, including Mining Geology and Oil Technology, and of the Department of Mining. As is the case everywhere at present there was much overcrowding, and some intending students in Mining Geology had to be excluded owing to lack of equipment. It is impossible in the space at our disposal to mention even a small part of the important work of teaching and research which is being carried on at this great college ; its activities cover almost every possible field of learning and technology to which geology can be applied, and we can only congratulate Professor Watts, Professor Cullis, and their staff on the brilliant results attained. It is pleasing to observe that a large proportion of the original papers published during the year by members of the various branches of the Department of Geology appeared in the pages of the Geological Magazine.

The Report of the Non-Ferrous Mining Committee

DURING the last few months we have frequently referred in our Editorial Notes to the proceedings of the Board of Trade Committee on the Non-ferrous Mining Industry. This committee—which was composed as follows: Mr. H. B. Betterton, M.P. (chairman), Mr. H. F. Collins, Mr. J. Harris, Dr. F. H. Hatch, Mr. R. A. Thomas, Mr. J. Wignall, M.P., and Sir Lionel Phillips, who was obliged to resign very soon after appointment—has now with commendable promptitude issued its report, a document of much interest from many points of view. While not primarily concerned with the geological aspects of British non-ferrous mining, the Committee have nevertheless investigated with some thoroughness certain geological matters in connexion with the tin lodes of Cornwall, the lead-zinc deposits of northern England, Scotland, and Wales, and the barytes of Shropshire. A most interesting extract is given from a report by Dr. Malcolm Maclaren to Messrs. Bewick, Moreing and Co., on the central mines of the Camborne-Redruth area, summarizing his views on the limits in depth of profitable tin working in that district. Dr. Maclaren points out that in most instances there is a marked falling off in tin-content at an average depth below the granite-killas contact of about 200 fathoms, or some 360 fathoms from the surface; only in one case, the well-known Dolcoath ore-body, did productive ore extend much below this; even this has failed at about the 500 fathom level. The facts here summarized are entirely consistent with the views as to the existence of definite mineral zones brought forward in the recent paper by Dr. W. R. Jones at the Institution of Mining and Metallurgy, and in the discussion on that paper by Professor Cullis, Mr. Rastall, Dr. Hatch, and other speakers. Favourable reference is also made to the projects for exploration below the abandoned shallow mines of this district by means of cross-cuts driven from the workings of the larger and deeper mines. It is certain that the granite-killas contact must extend far to the north of its surface outcrop at no very great depth; there is every probability that this contact is in point of fact an undulating one, and account must be taken of the fact that granite again comes to the surface at St. Agnes, where also there is well-developed mineralization. It seems probable that all the granite bosses of Cornwall and Devon are in point of fact local domes, cupolas in the American sense of the term, on the surface of a great bathylith, underlying the whole region at a rather small depth. It is of course uncertain what this actual depth may be, and in places it is probably below the limit of working under present conditions; there is also the further fact to be taken into account that in America it is believed that ore-minerals tend to concentrate themselves in the upper parts of these cupolas. Hence it is not safe to infer the existence of a tin-zone all over the upper surface of the bathylith. Nevertheless the widespread occurrence in the shallower mines of copper lodes is an encouraging feature from this point of view, suggesting the existence below them of the tin, wolfram, and arsenic zones. Several witnesses before the Committee asked for financial assistance from the Government to assist explorations of hitherto undeveloped deep-level areas, and it may be said that geological theory, so far as it goes, is favourable to the prospects of a successful issue.

Considerable space is devoted to a description of the projects for the drainage to lower levels of the Halkyn–Llanarmon area in Flintshire, which is considered to be perhaps the most important area of lead and zinc ores in the whole country. Here the problem is mainly geological, and depends wholly on the well-known water-carrying capacity of the Carboniferous Limestone and the consequent peculiar behaviour of the river system of that district. Here the geology is perfectly simple, and the whole question is now mainly financial; if the project for the continuance of a new sea-level drainage tunnel (which has been already started) can be carried out, some extraordinarily rich and productive veins can be worked down to a much lower level than at present, and a large addition made to the home supply of lead and zinc for many years to come. This seems to be pre-eminently a case for Government assistance. The case for a similar scheme for the Wanlockhead and Leadhills district appears to be less convincing, and neither the companies concerned nor the royalty owners seem to display much enthusiasm on the subject, owing to the immense capital expenditure necessary for a 7 mile tunnel in hard Palæozoic rocks.

Another point of geological interest arises in connexion with the lead-zinc deposits of Northumberland, Durham, and adjoining counties, which are chiefly in the Great Limestone, and are approaching exhaustion. Professor Louis suggested in evidence before the Committee that trial should be made of the Melmerby Scar Limestone as another possible productive horizon. This raises an interesting question as to the influence of the Whin Sill on ore-deposition in this neighbourhood, as to which little information seems to be available. It is generally stated that in Derbyshire lead-zinc ore-bodies are not found in payable quantities below the toadstone, a presumably impervious igneous rock; this suggests a downward movement of the mineralizing solutions. On the other hand, according to accepted modern theories of ore-deposition, the movement should be upward and the ores found *below* the igneous rock. To one unacquainted with local conditions the question at once suggests itself whether proper explorations have ever been carried out below the toadstone, or whether the absence of ore there is an assumption. With regard to the Whin Sill and the northern area the same question is pertinent; as is well known, the Whin Sill is transgressive, occurring at different horizons in the Carboniferous at different places, and it may be suggested that explorations should be carried out specially in localities where the sill is either immediately above or immediately below an important limestone, with a view to testing the validity of the two lines of contradictory argument as above set forth.

With regard to practical and administrative matters the Committee have dealt with many points, such as mineral leases, wayleaves, easements, the incidence of taxation, royalties, wages, State aid, and mine regulations in general. This is not the place to discuss any of these in detail, but it is permissible to say a few words as to what is in some ways the most important recommendation of the Committee, namely the constitution on a permanent footing of a Mines Department; it is suggested that the existing Mineral Resources Development Branch of the Board of Trade should be expanded and furnished with a suitable technical staff, including mining engineers and mining geologists, with a view to its ultimately forming a sub-department for metalliferous mining of a new Mines Department under the control of a minister. This is a most important recommendation, and it is highly desirable that it should be carried out at once. We have already more than once drawn attention to the existing overlapping of duties, waste of time and expense that will arise from the present multiplicity of authorities controlling the mining industry of the British Isles, and we look forward with confidence to the time when all of these will be centralized and co-ordinated into one organization adapted to the needs and potentialities of this great industry.

ORIGINAL ARTICLES.

A Recent Worldwide Sinking of Ocean-level

By Reginald A. Daly, Harvard University, Cambridge, Massachusetts.

LOCAL uplift and local sinking of the earth's surface have been fully demonstrated for past geological epochs. The amounts of these movements have generally been stated with reference to the present sea-level, and for the greater movements the statements of magnitudes are not seriously impaired by the fact that general sea-level itself has been shifting, upwards and downwards, through geological time. Among the causes for general or "eustatic" shifts of sea-level are: appropriate crustal movements whereby the volume of the ocean basin has been changed; delta-building and volcanic eruption on the sea-floor, the displacement of sea-water not being compensated by crustal sinking; volcanic addition of new water to the ocean; subtraction of water which becomes chemically bound during the alteration of rocks; glaciation on land, lowering sea-level by the abstraction of water from the ocean; deglaciation on land, raising sea-level; changes in the earth's centre of gravity and in her speed of rotation.[1]

Numerous as these possibilities are the proof of a eustatic change in shore-levels is not easy. In the following pages are recorded some field facts which suggest the probability of a sinking of general sea-level to the extent of about 20 feet during the human period. The

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[1] The writer has recently found that A. Tylor (Geol. Mag., 1868, p. 576, and 1872, p. 392) anticipated even Belt in relating the origin of coral reefs to the shift of ocean-level consequent on deglaciation. W. B. Wright (*The Quaternary Ice Age*, London, 1914, p. 417) believes the submerged forests of the British Isles prove a eustatic shift of 55 to 60 feet, if not of considerably greater amount, and attributes it to deglaciation.

suggestion is published, not to express a fixed conclusion, but to invite criticism by those familiar with shorelines in different parts of the world, for the testing of the idea is manifestly a worldwide problem.

The matter is important because it affects judgment as to the reality of many so-called uplifts of land or sea-bottom, and because a close study of the latest shift of sea-level may help to systematize the criteria for earlier and larger eustatic shifts.

FIELD OBSERVATIONS.

First Contact with the Problem.—The hypothesis of a Recent, negative shift of sea-level first suggested itself to the writer nearly twenty years ago, while engaged in the correlation of post-Glacial elevated strands in Labrador and Newfoundland with those of Quebec. The highest strand mapped between Newfoundland and Nachvak Bay, 500 miles to the north-west, was found to be strongly warped; its gradient varies from 1 to 3 feet per mile, measured along the coast and thus not at right angles to the isobases. The highest strand in Maine has maximum gradients of 5 or more feet per mile. Ice attraction fails to account for such high values and even for the lower gradients of the old strands around the Great Lakes, where also crustal warping is generally credited. On the other hand, the lowest emerged terrace along the shores of the Gulf of St. Lawrence was seen to be conspicuously level throughout a distance of 300 miles or more below Quebec City. The apparent uniformity of level prompted the question whether this particular strand had been abandoned by the waves because of a sinking of general sea-level. For lack of accurate levelling, definite correlation with the more closely studied, lowest beaches of Labrador was impossible, and with the data in hand serious belief in the hypothesis of a eustatic change was withheld.

However, that explanation was recalled by the discovery of new facts during recent field studies on the shores of New England, Florida, and the Samoan Islands. Meantime, Goldthwait had made a careful study of the St. Lawrence strand, to which he gave the name "Micmac terrace"; the results of his levelling agree so well with those made in the other regions mentioned that the suspicion of past years has become a hypothesis that seems to deserve more attentive consideration.

For the opportunity to collect data from the two tropical regions the writer is indebted to Dr. A. G. Mayor, Director of the Marine Laboratory of the Carnegie Institution of Washington.

Gulf of St. Lawrence.—In his excellent account of the Micmac terrace, Goldthwait writes: "Traces of wave work along the south coast of the Saint Lawrence were found at all altitudes below the upper limit of submergence. Contrary to expectation, again, there proved to be no shoreline below the highest one, with the exception of the twenty-foot [Micmac] strand, which possesses enough individuality of character, enough strength of expression, or enough continuity to indicate a long stand of the sea at any level. Distinct beach fragments were found at all altitudes, in such places as were peculiarly favorable to exposure to the open sea, or in supply of beach material. This is believed to indicate that the emergence of the Saint Lawrence valley from the Champlain sea was not accomplished by spasmodic uplifts, separated by intervals of repose, but was fairly steady and continuous. . . . In marked contrast with the weak beaches at higher levels, the shoreline which stands 20 feet above the sea is strong and continuous."[1] Similarly, the present writer could find no sure evidence of pronounced halts in the uplift of Labrador, where, however, the great strength of the bed-rocks and the general absence of thick glacial drift would in any case forbid the development of continuous beaches or benches in the time available. For the same reasons the topographic equivalent of the Micmac terrace would not be expected in Labrador, except quite locally, even if the emergence took place at identical rates in the two regions. The width of the Micmac terrace varies from a few feet to 1·5 miles or more. Though only a part of its width is due to wave-cutting, and though the formations affected are relatively weak, the 20 ft. higher level of the sea must have been steadily kept for a large fraction of post-Glacial time.

Farther east in the Gulf of St. Lawrence, at Anticosti, Twenhofel found elevated shorelines at intervals up to 350 feet above sea. "The lowest is between eight and fifteen feet above high tide." The corresponding terrace "reaches a maximum width of more than two miles and will average more than one-fourth mile". On the eastern two-thirds of the south coast for about 80 miles, this terrace is two or more miles wide, and is described as occurring in many other parts of the island.[2]

At Arisaig, Nova Scotia, on Northumberland Strait, Twenhofel noted a "raised" beach, roughly estimated to be 25 feet above sea (mean water-level ?).[3]

Maine.—"Throughout the region of Penobscot Bay the best defined and most widely developed terrace has an elevation of 20 to 25 feet above sea-level."[4] In the Rockland folio of the United States Geological Survey Bastin writes (1908): "The most widely developed terrace stands about 15 to 25 feet above mean tide." Along the Maine coast in general Stone noted evidence of a pause in the post-Glacial "fall of the sea" at an elevation of 20 feet above (mean ?) sea-level.[5] The present writer's field observations accord with these published statements, which indicate a recent,

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[1] J. W. Goldthwait, Amer. Journ. Sci., vol. xxxii, 1911, pp. 293–4.

[2] W. H. Twenhofel, Amer. Journ. Sci., vol. xxx, 1910, pp. 66, 69.

[3] Ibid., vol. xxviii, 1909, p. 147.

[4] G. O. Smith, E. S. Bastin, and C. W. Brown, Penobscot Bay folio, U.S. Geol. Survey, 1907, p. 13.

[5] G. H. Stone, Monograph 34, U.S. Geol. Surv., 1899, p. 53.

lengthened stand of the sea along the Maine coast at a level nearly 20 feet higher than the existing high-tide level.

The similarity of levels for the lowest terraces in areas so widely separated as the Maine coast and the Gulf of St. Lawrence, and the failure of the 300-mile Micmac terrace to show a distinct tilt, although it runs athwart the isobases of post-Glacial uplift, are both difficult of explanation by assuming crustal uplifts. Confidence in the alternative hypothesis of a eustatic shift was greatly increased by 1919 studies of shorelines in Samoa, about 7,000 miles from the St. Lawrence.

Samoa.—Mayor had already found wave-cut rock-benches, about 8 feet above high tide on all sides of Tutuila, the largest island of American Samoa.[1] The island is 16 miles long. At its eastern end is Aunuu Island, and about 60 miles farther east is Tau Island of the Manua sub-group. The writer found very fine wave-cut benches at 8 to 10 feet above high tide on Aunuu and Tau, and others at the same general elevation on Olosega Island, 7 miles west of Tau. The distance between the most widely separated benches is 75 miles; nowhere in that long line did the bench crests depart essentially from a constant level. Explanation by local uplift was at once seen to be highly improbable, for crustal uplift of such uniformity is unknown to geology.

Eight or ten feet of bench elevation does not, however, measure the total of recent emergence in Samoa. At several points in Tutuila large sea-caves were found. Their floors varied in height above high tide, from 14 or 15 feet at their mouths to 25 feet at the back walls of the caves. Many caves of similar forms and cut in similar rocks are being made by the surf of the present day. The lower lips of the newer caves are characteristically 4 to 6 or more feet below high-tide level, and the floors rise inwards to heights of a few feet above high tide. Hence the emerged caves were cut when the sea-level was nearly 20 feet higher than now. That assumption also explains the 8 ft. benches, for the cliffs now being cut on the Samoan headlands (where not protected by coral reefs) have regularly about 12 feet of water directly at their feet during high tide. The writer fully agrees with Mayor's conclusion that reef corals were not living on any of these Samoan shores when the emerged caves and benches were developed.[2] Hence the reefless, or nearly reefless, headlands of the present time are those where the relation between sea-level and bench-level of the earlier period is best determined. It may be added that no evidence of a negative shift of sea-level greater than about 20 feet could be found in the Samoan Islands. If they ever were submerged more deeply, the evidences have been removed by erosion.

The equivalence of the negative shift of sea-level in Samoa and along the east coast of North America is shown not only by its

[1] A. G. Mayor, Proc. Nat. Acad. Sci., vol. iii, 1917, p. 523.

[2] Ibid., p. 522.

amount, but also by the state of preservation of the strand marks. Allowing for lithological differences, cliffs, benches, caves, and chasms have comparable strength of development in the two regions, in each of which the sea must have worked a relatively long time at the 20 ft. level. Since the shift of level the surf has destroyed a part of each bench in Samoa, therewith doing work roughly equal to the destructive wave-work already performed on equally hard rocks in Maine.

Difficulties of an Inductive Study of Records.—The hypothesis of a eustatic change must meet the obvious test of matching the facts observable on the shores of every continent and nearly all islands. That the application of the test is not easy will be clear from the following considerations.

1. Most shores have not been studied with requisite thoroughness. The compilation of the published, appropriate records, incomplete as they are, is a herculean job. Apart from the time and physical labour involved, the compiler is baffled by the psychology of many authors, who have observed in the field and then written their records under the more or less unconscious control of the uplift hypothesis. Relevant and perfectly accessible facts have therefore not been noted. Moreover, the selection of data in statistical study has its own obvious danger for the compiler.

2. Writers have not always been careful to give the datum from which the level of each " raised " strand was measured. In general " sea-level " is mentioned without specifying mean level or high-tide level or any other unequivocal datum. The omission is serious for the compiler dealing with a shift of only 20 feet.

3. The marks of a higher stand of sea-level depend for their clearness on several highly variable factors, including: the strength and other characters of the shore rocks; the exposure of the coast as it affects the fetch and power of the waves; the power of tidal currents; the position of wave-base at the old shore, especially the depth of the rock-bench cut by the waves at the foot of a receding sea-cliff; the degree to which the records of the higher stand of the sea have been destroyed by the waves acting at present sea-level.

The influence of rock variation is well illustrated in New England, where glacial deposits were distinctly cliffed at the 20 ft. level, while the massive granites suffered little benching. As already stated, the contrast between the shores of the St. Lawrence and those of Labrador in this respect is very striking. Even where the shore materials were quite incoherent, as along young coastal plains, sea-cliffing might not have taken place systematically at all. Modern examples show prograding, rather than retrogression, of the shore-line. Thus the sea-cliffs of the 20 ft. strand would vary in height from zero upwards.

The crest of a storm beach is not sea-level. The more powerful the waves the greater is the difference of these two levels. From published texts one can not always be sure that due allowance has been made for the difference in estimating former sea-level from emerged beaches.

Variation in the position of wave-base is worthy of special attention. Waves running in on a flat shallow shelf are damped, so that wave-base approaches a minimum depth inshore. Wave-base is deeper along a steep-to shore, other things being equal. In the former case the foot of the sea-cliff is characteristically at or near high-tide level; in the latter case it is typically well below high-tide level, as exemplified in Samoa, where many headland cliffs plunge into water about 2 fathoms deep. Generally old strand-levels on oceanic islands are likely to be notably higher than the corresponding wave-cut benches, as well as 2 to 10 or more feet lower than the level crests of storm beaches.

4. Wherever a coastal region is now undergoing, or has recently undergone, a crustal movement, the search for local evidences of an earlier eustatic sinking of ocean level may give negative or doubtful results. The marks of the old strand may be drowned, or else elevated to heights which are not to be directly correlated with the heights of the old strand in undisturbed rocks.

5. In special cases the eustatic shift may locally cause a change in the tidal range, affecting the datum if this be high tide.

6. Finally the height of the old strand line above mean sea-level may depend on the cause of the eustatic shift. Suppose, for example, that a shift of level averaging 20 feet were due to a recent increase of the ice-cap on the Antarctic continent. Near the ice-cap sea-level would be kept, through gravitative attraction by the new ice, a little higher than it would be if abstraction of water from the ocean were the only cause for the change of level. In the northern hemisphere the lowering of sea-level would be all the greater because of attraction to the new ice.

For many reasons, therefore, the search for complete proof of the eustatic shift here postulated is bound to be prolonged. Meantime a preliminary study of some records made in separate mutually distant regions has been made, with results that also show the hypothesis to merit discussion and further testing. Certain examples may now be briefly reviewed.

British Isles.—The raised beaches of Scotland and Ireland are celebrated, and like the American cases already noted, occur in an area of uplift following deglaciation. In Scotland the uplift was differential, but according to most published statements the lowest beach is at nearly constant level, which is sometimes described as about 20 feet or about 25 feet above Ordnance datum. Ordnance datum is mean water-level at Liverpool, so that the beach varies from 15 to 20 feet above local high tide, according to these statements. Geikie writes: "The most prominent of all the raised beaches is that which lies at a height of about 20 or 25 feet above high water . . . varying in breadth from 6 or 7 miles to not more than a few feet." Along its inner edge are sea-cliffs, caves, sea-stacks, and skerries. "This beach must be more or less familiar to every one who has visited almost any part of the coast-line of Scotland."[1]

Many memoirs of the Geological Survey of Scotland bear references to this beach, which is described as seen "at frequent intervals", or as "conspicuous" or as the "best developed". In the Clyde area, the Loch Fyne area, Skye, and elsewhere, its fossil shells are those of species now living in Scottish waters. Clough writes: "With regard to the age of the 25-foot beach, the consensus of opinion seems to be that the elevation of the beach was completed in Neolithic times."[2]

In Jamieson's early account of the strand he states that a rise of 25 or 30 feet (above Ordnance datum ?) is indicated, and that it "seems to have been very general along the shores of this country". He concluded that the uplift was unequal; "consequently it is the land that has risen, and not the sea that has sunk."[3] Fifty years later Wright published a sketch-map of the "25-foot beach", showing a maximum height (above Ordnance datum ?) of over 35 feet near Loch Linnhe, in Western Scotland, from which point the elevation declines—to reach zero on the south-east and north-west shores of Ireland, in northern Wales, and in the North Sea.[4] Wright's placing of this strand-line does not altogether agree with the descriptions published by A. Geikie, Kinahan, Hull, and others, but would indicate late Neolithic warping.

According to Kinahan, "the 25-feet sea beach all around Ireland rises and falls very similarly to the levels of the present sea-margin," though he adheres to the uplift hypothesis as the only one to be considered in explanation. The old level is marked by cliffs, stacks, sea-caves, and beaches; on open seaboards they have been largely destroyed by waves breaking at present sea-level. From Wicklow, southward, the strand is at about the 22 ft. contour. North of Dublin Bay it is below the 20 ft. contour. In the old estuaries it has been placed nearly on the 25 ft. contour, perhaps illustrating the influence of the tides in causing different initial levels. Human relics and shells of species now living in the Atlantic have been found in the Irish beaches also.

Hull described the "25-feet terrace" as the most striking and continuous of all the "raised" beaches of Ireland, and correlates it with the 25 ft. strand in Scotland. However, he gives the average elevation of the Irish beaches as 15 feet.[5] The contrast in elevations

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[1] A. Geikie, *The Scenery of Scotland*, 2nd ed., London 1887, pp. 381–2.

[2] C. T. Clough, *The Geology of the Glasgow District* (Mem. Geol. Surv. Scotland), 1911, p. 192.

[3] T. F. Jamieson, Quart. Journ. Geol. Soc., vol. xxi, 1865, pp. 188–90.

[4] W. B. Wright, *The Quaternary Ice Age*, London, 1914, p. 422. According to a personal communication from Mr. Wright (November, 1919) the zero isobase should be drawn considerably farther south in Ireland and Wales.

[5] G. H. Kinahan, *Manual of the Geology of Ireland*, London, 1878, pp. 251–8; E. Hull, *The Physical Geology and Geography of Ireland*, 2nd ed., London, 1891, p. 137.

may be connected with the difference of datum-levels assumed in the two countries. Ordnance datum in Ireland is 8 feet below Ordnance datum for Great Britain (mean water-level at Liverpool, which is practically the same as in Ireland). In general, 25 feet above Ordnance datum in Scotland means 20 feet or less above high tide, the significant level.

For a total distance of about 1,000 miles along the southern shores of England, Wales, and Ireland, a "pre-glacial" terrace "has been traced almost continuously". It occurs also in France, from Calais to beyond Brittany. "Throughout the greater part of this district it stands uniformly some 10 or 12 feet above the present high-water mark, and maintains a remarkable parallelism with the present sea-level. This parallelism proves almost beyond a doubt that no permanent deformation by folding or faulting has taken place over this wide area since pre-glacial times."[1] The "pre-glacial" age is deduced from the presence of boulder-clay and early "Pleistocene" fossils on the rock-bench cut when the sea stood at the higher level. Wright holds that the old strand owes its position to a eustatic oscillation of sea-level.

The progress of discoveries and ideas concerning the lowest strands in the British Isles shows one kind of danger into which a compiler may run if the record of relevant facts is inadequate. Considering the many statements by good observers as to the continuity of the 20 ft. level or of the 25 ft. level all around both Great Britain and Ireland, it would look as if these islands could afford excellent corroboration of the eustatic hypothesis. When, however, strand-lines of about the right elevation are found to be partly "pre-Glacial" and partly post-Glacial, and when it is further suggested that the later beach-level has been deformed, the difficulty of using the British data is clear. If Wright's view as to the warping of the Neolithic beach (the 25 ft. or 20 ft. beach of Scotland and Ireland) is correct, then the relation of this very extensive strand-line to the eustatic hypothesis could only be established after the dates of the warping and the eustatic shift become known. Meantime the British Isles represent a region where the ascertained facts, in spite of their complexity, point to these islands as a field where special tests of the eustatic hypothesis should be made.

Atlantic Coastal Plain of the United States.—Other questions arise in connexion with the lower parts of Atlantic coastal plains recently emerged. For example, the Cape May formation of New Jersey and Pennsylvania and the correlated Talbot formation of Maryland emerged from the sea not many thousand years ago. Their surfaces lie in general below the 20 ft. contour, but strata with surfaces at 40 or 45 feet have been included in each formation. In the north

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[1] W. B. Wright, *The Quaternary Ice Age*, London, 1914, p. 423; *The Geology of the British Isles*, edited by J. W. Evans (*Handbuch der regionalen Geologie*, iii, 1), The Hague, 1918, p. 299. Cf. J. Prestwich, Quart. Journ. Geol. Soc., vol. xlviii, 1892, p. 263.

the "lower Cape May terrace" does not rise beyond the 20 ft. contour. Is there evidence of such a halt in the emergence of the Talbot formation ?[1]

Similarly, the lower division of the Pensacola terrace in Florida, like the Satilla terrace in Georgia, seems to correlate with the Recent 20 ft. eustatic shift. The Pensacola terrace "is a broad plain, rising less than 40 feet above sea level, and apparently including two divisions, one being less than 20 feet above, and the other from 20 to 40 feet above sea level."[2] The greater part of the Satilla terrace, which merges into the Pensacola terrace, "is 15 to 25 feet above sea level, but there are a few places which reach an elevation of about 40 feet. . . . If the coast region were uplifted 15 or 20 feet above its present elevation, a plain now submerged beneath the ocean waters would appear as an emerged terrace lying east of and parallel to the Satilla terrace, and separated from it by an escarpment. This plain would be analogous to the Satilla plain in all its essential features."[3] Since the Pensacola-Satilla terrace keeps a practically uniform set of levels for an air-line distance of 500 miles, the hypothesis of its emergence by crustal uplift seems hardly credible.

Florida Keys and West Indies.—Vaughan has deduced a recent sinking of sea-level of from 10 to 15 feet along the coral-reef keys of Florida, and "perhaps 10 to 20 feet" along the keys west of Bahia Honda.[4] He described New Providence Island of the Bahama group as "mostly a platform from sea-level to 20 feet in elevation", and the neighbouring Andros Island as having the same range of emergence. On New Providence Island he discovered a wave-cut scarp at 10 feet above "water-level", and other benches at only 3 or 4 feet above the sea, but he also found a sea-cave at Nicollstown Light, which indicates an emergence of about 18 feet.[2] This case of apparent conflict in the testimony of bench and sea-cave as to the amount of level-shifting is strikingly like that at Tutuila, Samoa, already described.

In Cuba the Seboruco "reef" represents a recent "uniform" emergence; it "borders the coast in most places" and constitutes many islets surrounding the main island. "Generally these are low, standing only a few feet above the water." In Jamaica Hill found "elevated reefs" at 25 feet and 10 feet above "sea-level",

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[1] Cf. M. Fuller, Prof. Paper No. 82, U.S. Geol. Surv., 1914, p. 222.

[2] G. C. Matson and S. Sanford, Water-supply Paper No. 319, U.S. Geol. Surv., 1913, p. 34.

[3] O. Veatch and L. W. Stephenson, Bull. 26, Geol. Surv. of Georgia, 1911, pp. 36, 437.

[4] T. W. Vaughan, "A Contribution to the Geological History of the Floridian Plateau": Papers of the Marine Laboratory, Carnegie Institution of Washington, 1910, p. 180. "Preliminary Remarks on the Geology of the Bahamas": ibid. 1914 p. 50. Yearbook No. 13, Carnegie Institution of Washington, 1914, p. 230.

and states that they are persistent on the north, east, and south-west shores.[1]

South America.—According to Branner, the Brazilian coast shows features indicating recent emergence, the amount of which is variously described as " a few meters " to 8 meters.[2] Halle found a " very distinct terrace at 6 meters above sea-level on Gable Island ", Patagonia, and another at 6 meters at the mouth of the Rio Grande River, 48 kilometres from Gable Island. The sands of the former terrace bear fossils showing that the contemporary sea had a temperature higher than that now reigning offshore. Halle adds : " These low terraces do not afford any unquestionable evidence of an unequal upheaval."[3] Andersson describes a sea-cut terrace at 3·5 meters on Beagle Channel, Tierra del Fuego, and says that it is the " same beach " as those on Gable Island and Navarin Island. He quotes Nordenskjöld's discovery of a very marked terrace at " about 10 meters above sea-level " on Usuaia Peninsula, Straits of Magellan.[4]

Graham Land, Antarctica.—Andersson also discovered a terrace at 7 meters " above sea-level " on Graham Land, Antarctica, indicating " upheaval " which " does not exceed a few meters ".[5]

New Zealand.—Considerable attention has been given by the Government Geological Survey to proofs of recent emergence in New Zealand, with results which may be tabulated as follows :[6] —

District.	*Elevation of " raised beaches " or benches.*
Thames subdivision	Maximum " over 25 feet " (datum ?).
Miranda, across Firth of Thames	10 to 12 feet above high-water mark.
Waihi-Tairua subdivision	Benches " several feet above high-water mark ".
Aroha subdivision	Correlated with the last.
Oamaru subdivision	12 ft. bench ; accompanying beach with Recent fossils ; Papakaio coastal plain at " 15 to 25 feet above sea-level ".

Australia.—According to Andrews, the numerous coastal plains, emerged beaches, and rock-benches of New South Wales " suggest an apparent elevation of the shoreline to the extent of a few feet in very recent time ". The heights of the beaches vary from 1 to 15 feet above high-water mark. " Similar indications of the apparent elevation of the shoreline for a few feet are to be found along the whole eastern side of Australia." The cause is attributed to " either an apparent rise of the land, or a retreat of the sea, to the extent of a few feet ".[6] Süssmilch believes that the New South Wales

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[1] R. T. Hill, Amer. Journ. Science, vol. xlviii, 1894, p. 203 ; Bull. 34, Museum Compar. Zoology, Cambridge, Mass., 1899, p. 99. Systematic discussion of the Atlantic Islands would include Bermuda, where R. S. Tarr (Amer. Geol. vol. xix, 1897, p. 293) found a recent terrace reaching 15 or more feet above sea.

[2] J. C. Branner, Bull. 44, Museum Compar. Zoology, Cambridge, Mass., 1904, p. 170 *et ante.*

[3] T. G. Halle, Bull. Geol. Inst. Univ. Upsala, vol. ix, 1910, pp. 99, 117.

[4] J. G. Andersson, Bull. Geol. Inst. Univ. Upsala, vol. viii, 1908, p. 182.

[5] Ibid., p. 57.

[6] Bulletin No. 10, 1910, p. 29 ; No. 15, 1912, p. 50 ; No. 16, 1913, p. 77 ; No. 20, 1918, pp. 112–13 and p. 4.

coast belt shows recent "uplift" to the extent of "about 10 to 20 feet." An estuarine deposit at Largs, with surface at 15 feet above high-water mark, has yielded more than 30 species of shells of animals now living in the adjacent water. Similar discoveries on the coast of Queensland are reported by Jack and Etheridge, the emerged beaches and plains (locally with recent fossils) having heights of from 10 feet to 20 feet above "sea-level".[1]

Cadell notes that the "raised beaches" of Western Australia are from 10 to 15 feet above sea-level. One of these is from 12 to 18 miles wide, and extends 25 miles inland. The beaches contain recent marine shells.[2]

Pacific Islands.—Many local, recent, negative shifts of sea-level have been recorded in the Pacific archipelagoes, where synthetic studies are needed in so many lines. A few of the records will suffice to raise the question whether the last shift of level in Samoa affected the whole Pacific basin. After his reconnaissance of the Paumotus, Agassiz wrote: "Nearly all the islands have been elevated a very moderate height and probably to about the same height." He gives the figure for Niau as "no greater than 20 feet" and for Rangiroa as 15 to 16 feet.[3] At Funafuti of the Ellice group, David and Sweet found the recent negative shift of level to be "at least 6 feet and almost certainly 16 feet". In another passage they write: "There must have been a land-elevation or a sea-sinking of at least 9 to 10 feet."[4] For the New Hebrides Mawson reports sea terraces, benches, and "raised" shore debris or coral in Santo, Efate, Epi, Malekula, Pakea, and Hui Islands, at heights of from 5 to 15 feet.[5] In his Murray Island report Mayor writes: "In common with other islands of the Torres Straits region, whether volcanic, calcareous, or continental in character, the Murray Islands exhibit a recently emerged shore platform about 3 feet above the present high-tide level."[6] On Bird Island of the Hawaiian Chain, Elschner found a "level terrace" a few feet above sea-level.[7]

As shown in Samoa and in the Bahamas, the observed heights of wave-cut benches on oceanic islands are likely to be 6 to 12 or more feet below the high-tide level ruling at the time of their cutting. "Raised" coral, too, is liable to give too small a value for a negative

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[1] E. C. Andrews, New South Wales Handbook, Brit. Assoc. Adv. Science, 1914, pp. 525, 532; C. A. Süssmilch, *Introduction to the Geology of New South Wales*, Sydney, 1911, p. 154; R. L. Jack and R. Etheridge, *Geology and Palæontology of Queensland and New Guinea*, London, 1892, pp. 614 ff.

[2] H. M. Cadell, Trans. Edinburgh Geol. Soc., vol. vii, 1897, p. 179.

[3] A. Agassiz, Memoirs, Museum Compar. Zoology, Cambridge, Mass., vol. xxviii, 1903, p. 20.

[4] T. W. E. David and G. Sweet, *The Atoll of Funafuti*, London, 1904, pp. 68, 84, 85.

[5] D. Mawson, Proc. Linn. Soc. New South Wales, 1905, pt. iii, pp. 400 ff.

[6] A. G. Mayor, Papers from the Department of Marine Biology, Carnegie Institution of Washington, vol. ix, 1918, p. 9.

[7] C. Elschner, "The Leeward Islands of the Hawaiian Group": reprint from the *Sunday Advertiser*, Honolulu; 1915, p. 9.

shift. Until the delicate problem of the relation between the emerged forms and the corresponding sea surface has been worked out, both as to general criteria and as to the local application of those principles, the actual amount of delevelling registered in the Pacific Islands cannot be definitely stated.

California.—Japan, Alaska, and California are examples of the lands where local movement of the earth's crust, upwards or downwards, have taken place during the last few decades. Strand-marks of an ocean-level, which some thousands of years ago was higher than now, must there have altitudes different from contemporaneous markings in more stable regions. Identification of the 20 ft. strand is thereby made specially difficult. Yet Lawson's observations on the emerged zone at Carmelo Bay and Monterey, California, are suggestive for future research. He notes that the emerged terrace reaching 25 or 30 feet above sea-level is the " most defined and persistent elevated terrace in this coastal region ", and concludes that the sea beat on the higher shore about as long as it has worked at the existing level.[1] Has the emerged terrace a height slightly greater than that of the Micmac and other terraces because California has been specially affected by diastrophism during the recent period ?

AMOUNT OF THE EUSTATIC CHANGE.

Without further multiplying examples, those so far mentioned may be reviewed conveniently by the use of the following table.[2] Its full meaning cannot be understood without recalling certain principles. In each case where the author of a record uses " sea-level " or " water level " as his only datum, reference to the more significant and less equivocal high-tide level is not directly possible. The fifth column of the table therefore has many blanks. A wave-cut bench is likely to give too low a value for the emergence; a storm-beach, too high a value. Coral reefs give too low a value unless they can be shown to have grown up to the sea surface (mean or high-tide level) before the emergence began. Even in that instance their crests may have been somewhat abraded by storm waves just after the sea-level began to sink, for a dead coral reef is a friable structure. Special note should be taken of W. B. Wright's view that the British 25 ft. beach has been warped.[3]

In spite of all uncertainties, columns 4 and 5 of the table show that the negative eustatic shift of ocean level which suffices to explain the facts, is close to 20 feet. It may have been a little less ; it was probably not as much as 25 feet.

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[1] A. C. Lawson, Bull. Dep. Geol. Univ. California, vol. i, 1893, p. 53.

[2] In a verbal communication Dr. E. O. Hovey has stated that at many parts of the Greenland coast he observed beaches with crests 15 to 20 feet above mean sea-level.

[3] See reference above, and also GEOL. MAG., Vol. viii, 1911, p. 99.

SUMMARY OF DATA REGARDING RECENT EMERGENCE.

Region.	Features.	Heights given (feet).	Datum stated.	Height above high tide (feet).	Remarks.
Gulf of St. Lawrence	Micmac terrace	14–23	High tide.	14–23	Specially developed.
Anticosti	Terrace	8–15	,, ,,	8–15	Ditto.
Arisaig	Beach	25	Sea-level.	—	Roughly estimated.
Maine	Beaches, benches	15–25	Mean tide.	10–20	Specially developed.
Scotland	,, ,,	20–25	Ordnance.	15–20	Ditto.
,, (Wright)	,, ,,	20 (?) – 35 +	Ordnance (?)	(?)	Ditto.
Ireland	,, ,,	15–25	Ordnance.	15–20 (?)	Ditto.
,, (Wright)	,, ,,	0–25 (?)	Ordnance (?)	(?)	Ditto.
New Jersey	Lower C. May terrace	20	Sea-level.	—	Uniform levels for long distance
Maryland	Talbot terrace (in part)	20	,,	—	Ditto.
Georgia	Satilla terrace (greater part)	15–25	,,	—	Ditto.
Florida	Lower Pensacola terrace	20	,,	—	Ditto.
	Keys	10–20	High tide (?).	—	Ditto.
Bahamas	Benches, sea-caves	3–20	Water-level.	—	Platforms wide; sea-cave at 18 feet.
Cuba	Reef	" Few feet."	Sea-level.	—	Persistent.
Jamaica	Reefs	10, 25	,,	—	,,
Brazil	Beaches, terraces.	20–25	,,	—	
Patagonia	Terraces	12–32	,,	—	Accord at distant points.
Graham Land	Terrace	23	,,	—	
New Zealand	Beaches, benches, coastal plain	10–25	,,	—	See table above.
East Australia	Ditto	10–20	,,	—	Uniform emergence.
West Australia	Ditto	10–15		—	
Samoa	Benches, sea-caves	8–15 +	High tide.	8–15 +	Uniform emergence.
Paumotus	Emerged limestone	15–20	Sea-level.	—	
Funafuti	Reef coral	6–16 (?)	High tide.	6–16 (?)	
New Hebrides	Terraces, benches	5–15	Sea-level.	—	
Murray Island	Benches	" Few feet "	High tide.	—	
Bird Island	Terrace (level)	,, ,,	Sea-level.	—	
Carmelo Bay	Terrace	25–30	,,	—	Persistent.

CONTEMPORANEITY AND AGE OF THE STRANDS.

A second test of the eustatic change is naturally to be found in the expectation that the delevelling should be essentially synchronous in all parts of the ocean. In fact, observers dwell on the recency of the sea-level shifts registered in all of the illustrative cases. Fossils in the St. Lawrence, Scottish, Irish, Cuban, Patagonian, New Zealand, Australian, Funafuti, Murray Island, New Jersey, Maryland, Georgia, and Florida beaches, reefs, or coastal plains belong to species now living in the adjoining seas, or, exceptionally, to species now living in slightly warmer water. Great recency is also shown by the relatively small damage done by erosion to the strand marks, except in the case of those exposed to powerful surf.

The beaches of the higher latitudes are clearly post-Glacial, and also of date later than the post-Glacial uplifts following deglaciation. Brögger puts the completion of the last 4 metre to 8 metre emergence of the Christiania region at about the year 500 B.C. The development of the corresponding sea-cliffs, benches, and other strand marks is referred by him to the late Tapes (Neolithic) period, between 1400 B.C. and 2400 B.C. All Tapes time is taken to lie between 1400 B.C. and 6700 B.C. During the late Tapes period the Christiania climate was about 2° C. warmer than now.[1] Traces of Neolithic man have been found in the 25 ft. beaches of the British Isles. The emergence of this beach in North Ireland seems to have been completed during Neolithic times.[2]

Perhaps fuller direct evidence for contemporaneity among the lowest beaches may be discovered through the use of fossils. It is significant that the fossils in the Patagonian beaches, like those of Norway, betoken water warmer than the adjacent sea.

Simultaneous emergence for the many separate regions is the more credible because of the similarity in the histories of their respective coasts before emergence. Repeatedly one encounters the description of terrace, bench, or beach near the 20 ft. level as the best developed, the most conspicuous, or the most persistent in a region characterized by "raised" strand marks; illustrations are noted in the foregoing table. Thus, the different regions must have had sea-level nearly constant for a considerable time, during which the strand marks were well incised. This widespread accordance itself must deepen suspicion that local diastrophism has not been responsible for the recent emergence of so many continental and island coasts.

In conclusion, the facts in hand appear to permit belief in the possible synchrony of the different strand markings and emergences here considered, but this second test of the general hypothesis also leads more surely to questions than to definite answers.

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[1] W. C. Brögger, Norges geol. Unders., No. 31, 1901, p. 713, and No. 41, 1905.

[2] W. B. Wright, *The Quaternary Ice Age*, London, 1914, pp. 384–5.

CAUSE OF THE EUSTATIC CHANGE.

Before the fact is established it would be idle to dwell overmuch on the explanation of a 20 ft. drop in ocean level. If lands in both hemispheres, in high and low latitudes, emerged simultaneously and to a nearly equal amount, the cause of the emergence cannot be found in a change in the earth's centre of gravity nor in a change in the speed of her rotation. There is no evidence compelling belief that the ocean basin has been so enlarged in recent time as to cause a negative 20 ft. shift of sea-level. More hopeful is the hypothesis of an increase in the volume of existing, non-floating glaciers, an increase taking place a few thousand years ago. If the Antarctic ice-cap were then thickened to the average amount of about 700 feet, an average sinking of sea-level to the extent of nearly 20 feet would be inevitable.

In favour of this suggestion would be evidence of a worldwide oscillation of climate, like that which seems to have affected the Christiania region in Recent time. If the whole earth was in the Tapes period a little warmer than now, less water may have then been taken from the ocean to build the ice-caps; sea-level was a little higher than at present. The oscillation as a whole would be but an incident in a series of climatic changes which began with the opening of the Glacial period.

CONCLUSION.

The facts on which the hypothesis of a general post-Glacial fall of sea-level is based belong to three groups.

Because of the recency of strand lines now about 20 feet above high-tide level, many of these lines should not have undergone important deformation, and if their emergence was due to the eustatic shift their accordance of level should be observable. Notwithstanding the difficulties attending a canvass of the world's coastlines, a comparison of published observations seems to show that the speculation will bear the test of a fuller induction founded on special field work.

Naturally less troubled by the danger of subjectivity, the conclusions drawn from a study of the Micmac terrace or the lowest coastal-plain terrace to the southward of New York City are now perhaps more compelling. Practical uniformity for the terrace level along 300 miles of coast in the one case and along nearly 1,000 miles of coast in the other is certainly not expected on the uplift hypothesis, which likewise does not easily explain the strikingly accordant levels of Samoan benches at points only 75 miles apart.

A third group of facts, relating to the necessity of synchrony for the different strands abandoned by the sea, is meagre, but so far as it goes this evidence permits the main hypothesis, and its analysis suggests methods for future research.

The combination of all three groups of observations is much stronger than any one of them. For that reason the eustatic hypothesis has seemed worthy of statement. The search for proof of eustatic shifts during more remote periods might be easier if even a small modern movement of the kind were proved, especially if its cause were also determined.

Note on the Age of the Milburn Group.

By A. D. N. Bain, B.Sc.

On the western side of Cross Fell lies a group of beds consisting of andesitic lavas and ashes, with intercalated beds of shale. The shales are tranquilly bedded, testifying to their having been deposited in quiet water. It has therefore been inferred that the igneous material is volcanic, and was poured out on a sea-floor. The beds were first described by Harkness,[1] later by Goodchild,[2] who gave the name " Milburn Group ", and subsequently by Professors Nicholson and Marr.[3]

The exact age of these beds could only be approximately determined because of the scarcity of determinable fossils obtained from them. Goodchild recorded *Didymograptus murchisoni* (Boeck), and Professors Nicholson and Marr recorded *Diplograptus dentatus* (Brongn.).[3] Professor Marr assigned them to either the Lower Llandeilo or the uppermost part of the Arenig, at the same time expressing a hope " that local observers will pay special attention to the fauna of these beds, as the exact determination of their age is a matter of considerable importance ".[4] Later Goodchild grouped them with the Ellergill Beds, a group of earthy slates underlying the Milburn Group and of about the same age, as being equivalent to the lower part of the Volcanic Series of Borrowdale.[5]

It is in Wythwaite Hole that these beds are best exposed and where they have been generally studied. A good exposure occurs in a similar " hole " to the east of Wythwaite Hole proper, where a band of shale is exposed, quite regularly bedded and lying between masses of andesitic lava. It is about 3 feet thick and dips to the south-east. The lavas above show regular parallel banding, dipping at a greater angle in the same direction.

From this band of shale the following graptolites have been collected by the author[6]:—

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[1] Quart. Journ. Geol. Soc., vol. xxi, 1865, pp. 235, 340–1. Cf. Harkness, Quart. Journ. Geol. Soc., vol. xix, p. 127.

[2] Proc. Geol. Assoc., vol. ix, No. 7.

[3] " The Cross Fell Inlier ": Quart. Journ. Geol. Soc., vol. xlvii, 1891, p. 502.

[4] Geol. Mag., 1894, p. 128.

[5] *The Geology of the Country between Appleby, Ullswater, and Hawes Water.* Mem. Geol. Surv. England and Wales, Sheet 30 (New Series), 102 S.W. (Old Series), pp. 34 and 39.

[6] A *Phyllograptus*, the species of which has not yet been determined, has also been obtained.

Didymograptus bifidus Hall.
Didymograptus stabilis Elles & Wood.
Didymograptus nanus Lapw.

From the Ellergill Beds exposed in the lower part of Eller Gill I have obtained *Glyptograptus dentatus* (Brongn.). Since these fossils are characteristic of the *Didymograptus bifidus* zone, it would seem that the Milburn Group and the associated Ellergill Beds belong to this zone, and that here, too, volcanic activity began in Upper Arenig time.

In conclusion, I desire to express my sincere thanks to Miss Elles for having determined the graptolites and permitting me to see her determinations, and to Professors Sibly and Marr and Dr. Woolacott for advice.

Isostatic Measure of the Rocky Mountains.

By Charles Keyes, Des Moines, Iowa.

AMONG the enisled high plateaux of Eastern Utah the brilliant isostasy theory had its birth. When these arid mountains first became the subject of special description, about 1880, no such thing as a distinctive desert geology was entertained. Possibility of a definite geographic cycle in land sculpture was one of the modern earth conceptions yet undreamed. Competency of the wind as a general erosive agency was not yet established. Operation of epeirogenic movements was little understood. Omission of such basic considerations necessarily led to curious aberration in interpretation of the phenomena presented by lands of little rain.

Following closely the rather unscientific Powellian policy of geological saisissement, Captain Dutton entirely missed the larger physiographic significance of his wide observations on the prodigious erosion which the Utah region had manifestly undergone in relatively recent geological times. He readily fell into speculations along other lines. With him inductive reasoning took a tectonic rather than a physiographic turn.

Principal among the Duttonian meditations was an estimate of the crustal effects of sedimental loading and unloading through erosion. Reviving astronomer Herschel's well-known view that areas of sedimentation should be regions of insinking of the earth's crust, the endeavour was to show that the converse of this was also true, and that the Utah and Great Basin regions, from which enormous volumes of rock-waste had been so recently removed, should display the evidences of continual and notable upraising. The hypothesis of isostasy was just beginning to take form.

With bent of mind tectonic, Dutton turned eyes to the westward for substantiation of his hypothesis. In the Basin ranges he believed that he had found satisfactory proofs. With Gilbert, Powell, and Russell he fancied that those desert mountains were floating on the earth's soft interior, much after the manner of ice-cakes in a river at time of the spring break-up. To this quartette the erosional derivation of the Basin ranges seemed entirely out of question. The potency of eolation in arid lands was little suspected.

In the seventies of the last century Dutton was really unable to turn his attention profitably to the Rocky Mountains rearing their peaks to the east of him, in order to test his hypothesis. Geologically the Cordillera was too little known. Its extent was too vast to draw upon in hasty conclusion. It required half a century of uninterrupted investigation by many persons to dislodge the facts that had critical bearing upon fantastic musings. Newer evidences appear conclusive.

The Rocky Mountains seem to be exceptionally well suited to determine the span of isostasy. They occupy a tract which from the earliest geological times has undergone continuous diastrophic oscillation. The area is one which has been repeatedly uplifted. It is one which has suffered again and again extensive planation. The orographic change is never so great as entirely to obliterate the salient features of the different movements. Later upraisings and down-sinkings are especially well marked. The geologic record of events is unusually full.

Since Palæozoic times the Southern Rockies have experienced no less than four distinct and notable upliftings. In the same time they have suffered a like number of total effacements. Each of the ancestral Rockies has appeared no less majestically than the mountains of to-day. Each of the old levellings has been down to the surface of the sea. Peneplanation has been as perfect as is probably ever attained. Great planation periods were during Comanchian, Laramian, Miocene, and Recent times.

Comanchian peneplanation is particularly widespread. It affects the whole continental interior from the Rio Grande to Hudson Bay and from the Sierra Nevada border to the Mississippi River. Even to this day its essential characters are unusually well displayed. Throughout its broad expanse the great Dakotan sandstone conspicuously marks its stratigraphical position and preserves its features. The old plain is one of the smoothest known in all geological history. Only in a few places do there exist any unconsumed residuals standing out as low monadnocks above the general level.

According to the fundamental premise of the isostasy hypothesis, mountains continually rise because of the removal of their summits through erosion, thus lightening the local crustal loads. On the other hand, according to Herschel, areas of sedimentation, or loading, should be tracts of notable crustal insinking. Singularly, the Jurassic ancestral Rockies do not appear to have grown higher as their substance wasted away. They allowed themselves to be worn down to the very level of the sea.

After reaching sea-level, when all their positive volume had vanished, the tract which the Rocky Mountains once occupied, instead of continuing to rise, or at least remain stationary, proceeds to sink. Indeed, the area may have begun to sink long before it reached base-level. At any rate depression is active until the old plain attains an horizon more than two miles beneath the surface of the ocean. Where once lofty mountains pierced the sky, marine sediments 10,000 feet in thickness accumulate. In spite of the removal of its former great load the net result of the regional vertical movement is notably negative.

Neither does the insinking of the earth's crust in this region appear to have taken place *pari passu* with extensive transference of sediments. Cretacic depression manifestly initiates itself long prior to the beginning of the sedimental loading, perhaps before the mountains were completely demolished. Then, curiously enough, so soon as the enormous loading is finished the region is uplifted again into lofty ranges, as towering, perhaps, as any which appear before or since. Instead of the sequence of events satisfying the isostatic equations, the very reverse proves true all through. Thus is regional unloading succeeded by crustal downsinking, and orogenic upraising is accomplished under maximum load. Surely some orographic force other than the isostatic one is at work.

An especially noteworthy feature concerning the Jurassic revolution in the Southern Rocky Mountain region is that it is not an isolated or unconnected catastrophe. An identical sequence of events is repeated a little later in Laramie time, and again in Miocene time. To-day the same process is going on for a fourth time.

During the epoch when Laramian sedimentation was proceeding around the ancestral Rockies, the latter were themselves razed to the level of the sea. Under a prodigious load of sediments, more than two miles in thickness, the tract is uplifted a distance of between four and five miles; and that before it is appreciably unloaded. Again it is worn down to the ocean level. With the lightening of load on account of erosion there appears to be no recognizable uplifting. After base-levelling, the area instead of rising sinks, until the peneplain is buried under miles of Tertiaries.

In the Miocene period, for a third successive time, are the Rocky Mountains reared to lofty heights, only to be reduced to a low-lying plain. Recently, notable uplifting is repeated. The rejuvenated streams are now about completing their canyon-cutting. On the flanks the winds are levelling and lowering the surface. Soon the mountains will be turned into plain. Are they destined to a new engulfment and a new sinking a mile or two or more beneath the waters of the sea? Experience of the past for three successive times proclaims the affirmative.

In all four orogenic cycles the procedure is the same. Removal of load is not accompanied by further upraising. Rolling of oceanic waters over the tract precedes regional loading. Maximum areal loading is followed by great uplifting. Every stage is met with phenomena diametrically opposed to that which isostasy logically and vitally demands. The isostatic hypothesis fails utterly to sustain itself before such an array of critical geological testimony.

Turning to the arid Great Basin, from which the chief advocates of the isostatic hypothesis drew their main inspiration, we find that the theory is everywhere rendered nugatory. The hard-rocked mountains do not appear to be growing higher through extensive unloading, but only relatively so because of the fact that erosion peculiar to the desert is going on much faster over the soft intermontane plains. The tectonic structures are mainly not recent but comparatively ancient. The entire surface of the region seems to have been epeirogenically uplifted long prior to the formation of the mountains. In the arid regions the evidences are therefore really against isostasy.

The mountain-tops of to-day probably mark approximately the level of the old uplifted peneplain surface. Genesis of the positive features of desert landscape does not appear to be tectonic but deflative.

The isostatic hypothesis receives strong support from mathematics. Certainly mathematics is a mill which grinds exceeding fine. But, as many thinkers have remarked, what comes out of the mill depends very largely upon what is fed into it. So that, concerning earth problems, there is often little to choose between the rough guess of the geologist and the painstaking calculations of the mathematician.

In view, then, of the recent observations in the Rockies, bearing critically, it seems, upon the theme of isostasy, it appears that the mathematical equations will have to be radically modified in order properly to satisfy the necessary consequences lately derived from the field, or else they will have to be given up as pure fictions.

So far as we are able now to discern, it seems quite manifest that in the hypothesis of isostasy effects are mistaken for causes. At the time, a hundred years ago, when Herschel advanced the idea of crustal insinking, because of sedimental loading, the accepted notion concerning the earth's interior was that it was in a highly plastic condition. Some such conception also pervaded the minds of those who were instrumental in formulating the hypothesis in its later aspects. Since that time, now nearly half a century ago, the phenomena which were so earnestly cited in support are not only readily explained in far simpler ways, but the observations themselves are found to be curiously distorted on account of fancied conditions.

It is not at all strange that the Rocky Cordillera should, on the one hand, so strongly belie the verity of the isostatic hypothesis, and, on the other hand, point so conclusively to the strictly telluric nature of its genesis, and of orogeny in general. Referring characteristic mountain tectonics with which we are acquainted to the secular diminution in rate of the earth's rotation, all the principal orographic features are satisfactorily reproduced in the laboratory.

At best, then, mountain genesis appears to be merely a feeble expression of the larger telluric properties of our globe. As such it is fit subject for most rigid analysis.

The Metamorphism of the Carrock Fell Gabbro; with a Note on the Origin of the Sulphide Veins of the Caldbeck Fells.

By Sidney Melmore, B.Sc., F.G.S.

WITHIN the last two years a cutting has been made at the south-east corner of Carrock Fell, a few yards north of the village of Mosedale, for the purpose of obtaining road-metal. This has opened an interesting section near the margin of the intrusion. The rocks exposed comprise two varieties of gabbro and enclosed Eycott lava. Of the two types of gabbro, that next the lava is of the quartz-bearing variety, exhibiting the prevailing dark-green tint in the hand specimen, and carries large flakes of biotite. This is succeeded by the same type of gabbro, but in a highly metamorphosed condition, at once evident in the hand specimen, which is lighter in colour, primarily owing to the decomposition of the felspars.

Examination of the first gabbro in thin sections under the microscope shows that it also has been metamorphosed, though in a lesser degree than the lighter-coloured variety. The felspars are of the oligoclase-andesine type; the central parts of the crystals are in a saussuritic condition, while the ends are free from decomposition. This condition is particularly noticeable in the larger crystals, and suggests secondary deposition of material differing slightly in chemical composition from the original matter, since the crystals show zonary extinction, and the twin-lamellæ seem to broaden out somewhat at the ends. The extinction angle is greater for the inner than for the outer zones. The crystals themselves are surrounded and cut up by irregular strings of chlorite. Some of the felspars occasionally contain a few minute irregularly shaped colourless plates, depolarizing in colours of a high order, and are doubtless sericite, though they are too small for identification.

The original pyroxene has been converted into pale-green serpentine, which occurs in areas with a more or less sharply defined outline, and having a platy structure. The central parts of these areas are in some cases occupied by small grains of magnetite in a fine-grained mosaic of strongly depolarizing material, and in others by chlorite. Separate fragments of chlorite also occur exhibiting a fibrous structure. Biotite is largely altered to magnetite. This change seems to have progressed from one side of the mica-flake to the other, and can be found in all stages of development.

A specimen picked out of the heap of material already quarried contained a layer of pectolite, about 3·5 cm. in thickness, surrounded by rock identical in every respect to that already described, except perhaps that the biotite is everywhere completely converted into magnetite.

The pectolite gave on analysis :—

SiO_2	51·94
Al_2O_3 and trace Fe_2O_3	1·56
CaO	14·70
SrO	19·52
MgO	trace
Na_2O	6·08
K_2O	2·26
Combined water	3·40
	99·46
Specific gravity	2·79

Small masses of calcite about 1 cm. across and containing traces of strontium are sometimes found with the pectolite.[1]

A section cut from this pectolite specimen showed under the microscope a thin layer of white mica between the pectolite and surrounding rock, while a narrow string of this mica ran parallel to the main vein of pectolite and at some distance from it. Flakes of sericite can be seen in the felspars adjacent to the vein. Analysis of the rock itself showed only a trace of carbon dioxide, with 0·074 per cent sulphur.

The greater part of the lighter-coloured gabbro, which is about 2 feet in thickness at the margin of the intrusion, consists of plagioclase in a more advanced state of decay; the whole of the crystal is reduced to a translucent mass, through which the core of previously decomposed matter can still be seen in some instances.

Almost colourless serpentine occurs in places, associated with magnetite in large, approximately square sections, and in small granular inclusions, while separate areas of fibrous chlorite are also present.

Occasionally small hook-shaped areas of isotropic material with felspar inclusions can be detected between the felspar crystals. There are also a few well-defined crystals, giving a biaxial interference figure and possessing very weak double reflection, that probably represent a member of the zeolite group. The quartz present in the rock is full of liquid inclusions, the length of the larger of these being about 0·006 mm. and the diameter of the bubble 0·0015 mm.

This rock, which represents a maximum degree of metamorphism observed, loses 2·12 per cent of its weight on ignition. For the normal quartz-gabbro Dr. Harker gives the loss on ignition as 1·50 per cent.[2]

From the above account it may be concluded that hydrothermal metamorphism has taken place at the margin of the gabbro intrusion, resulting in the serpentization of the original pyroxene, accompanied

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[1] The material taken for analysis was free from calcite.

[2] Quart. Journ. Geol. Soc., vol. l, 1894, p. 323.

by local sericitization and the formation of pectolite, with extensive alteration of the felspars in the most intense stage.

Evidence of similar changes is to be found in the case of the interfusion rock between the gabbro and granophyre. At the foot of Furthergill Syke there is a variety of this rock in which calcite (without strontium) is uniformly distributed throughout the mass, but otherwise corresponding to that marked "No. 2" in Dr. Harker's section across Furthergill Syke, the specific gravity of which he found to be 2·805.[1] The specific gravity of this altered variety is 2·68. Analysis showed 0·80 per cent of carbon dioxide, corresponding to 1·82 per cent calcite; and 0·023 per cent sulphur.

Amongst the heaps of mine refuse at Roughtengill are to be found specimens of the more basic variety of interfusion rock, containing amygdules and small offshoots of calcite surrounded by a thin layer of pink felspar. This calcite contains traces of strontium.

It has long been supposed that the Carrock Fell complex represents the focus of igneous activity that gave rise to the sulphide veins of the Caldbeck Fells. The structural relationship and other considerations pointing to this conclusion have been demonstrated by Mr. Postlethwaite.[2] Further evidence is also afforded by the way in which the metallic contents of these veins fall off as we recede from this centre, so that at Pottsgill and Ruthwaite the gangue of quartz and barytes makes up practically the whole of the vein contents. It seems reasonable, therefore, to infer that the formation of the sulphide veins is to be correlated with the type of metamorphism already described. It is noteworthy that though the sulphur contents of the normal ultrabasic gabbro from Furthergill Syke is considerably below the average for this type of rock, and that the granophyre at the top of Carrock Fell is also low in sulphur, there is, nevertheless, an increase in the amount of this element at the margin of the intrusion, due either to magmatic segregation or to removal of sulphides from depth by the agents that have brought about the marginal metamorphism. The percentage of sulphur in the rocks under consideration is:—

	Sulphur per cent.
Iron-ore gabbro	0·008
Granophyre	0·014
Interfusion rock . . .	0·023
Serpentinized quartz-gabbro .	0·074

From this point of view the sulphide veins are to be regarded as contact veins in the sense of Beyschlag, Vogt, and Krusch's definition, i.e. as "fissures standing open in the contact zone . . . filled with ore deposited from solutions issuing from the magma".[3]

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[1] Quart. Journ. Geol. Soc., vol. li, 1895, p. 133.

[2] Trans. Cumb. and West. Assoc. Lit. and Sci., vol. xv, 1889–90, p. 78.

[3] Beyschlag, Vogt, and Krusch, "The Deposits of the Useful Minerals and Rocks": Trans. Truscott, vol. i, 1914, p. 69.

On a Rich Fauna in the *varians* Zone of the Lower Chalk near Reigate.

By Gerard W. Butler, B.A., F.G.S.

THIS fauna resembles that found by Mantell a hundred years ago in the "Chalk Marl" of the South Downs at Hamsey, near Lewes (see specimens in the Natural History Museum, South Kensington), but the occurrence of such a fauna in the familiar North Downs of Surrey seems hitherto unknown. I think, then, that this find should be recorded, that others may, when possible, see how far the faunal richness is local.

The place where my son, R. W. Butler, and I, after living seventeen years in Reigate, stumbled upon this fauna, is on that well-known track, the "Pilgrims' Way"; but it is quite a small excavation, from which a few cartloads of Chalk have been taken for the land. It is about a quarter of a mile west of the "Horseshoe", and where the cart-track from Colley House Farm (south of the railway) meets the "Pilgrims' Way". On the 6 in. Ordnance Survey Map, 1915, Sheet xxvi S.W., it is 3·85 inches from the top edge and 2·35 inches from the right edge. From here a path up the hill runs north-east to some small pits, indicated on this map, where some 50 feet higher than the exposure here described the nodular "Melbourn Rock", the base of the Middle Chalk, is seen. Thus the horizon, though by its fossils clearly in the *A. varians* zone, is above the middle of the Lower Chalk; but in the absence of a continuous section I do not know how much it is above the Upper Greensand.

The fossils found include:—Cephalopoda: *Nautilus*, *Anisoceras armatum* J. de C. Sow., *Turrilites costatus* Lam., *Baculites baculoides* Mantell sp., *Schlœnbachia varians* J. Sow., *Schl. coupei* Brong., *Acanthoceras rotomagense* Brong., *Acanthoceras* sp. (an abnormal specimen, with right and left sides different, intermediate between *A. rotomagense* and *A. mantelli* Sharpe), *Scaphites striatus* Mantell. Lamellibranchiata: *Plicatula*, *Lima* (*Plagiostoma*) *globosa* J. de C. Sow., *Lima* sp., *Limatella*, *Pecten beaveri* Sow., *Inoceramus* (2 or more species), *Cucullæa*, *Cardita*, *Cyprina*, *Tellina*, *Pholadómya decussata* Mantell sp., *Cuspidaria*, *Corbula truncata* Sow., and as more doubtful genera *Pectunculus* and *Nucula*. Gasteropoda: *Pleurotomaria*, *Solariella gemmata* J. de C. Sow., *Solarium*, *Turritella*, *Cerithium*, *Aporrhais* (2 or 3 species), *Avellana cassis* d'Orb. Brachiopoda: *Lingula*, *Rhynchonella mantelliana* Sow., *Rh. martini* Mantell, *Terebratulina striata* Wahl., *Terebratula*, *Kingena lima* Defr. Other fossils: *Discoidea cylindrica* Lam., Echinoid spines, *Serpula*, tooth of *Lamna appendiculata* Agassiz sp., and some black carbonaceous traces of vegetable matter.

In the case of all the Cephalopods, all the Gasteropods except *Solarium*, and all the Lamellibranchs except *Plicatula*, *Lima globosa*, and some of the *Inocerami*, the shell has disappeared, its place being taken by chalk, sometimes ironstained. The chalk, except in the case of Cephalopod septa, seems always to break so as to show the outside only of these casts, which, if not smudged, are all right for species easily identified by the external form and markings, but are not so good for the small Lamellibranchs.

Some of the best and most interesting specimens were found by my son, while the most interesting of all, the *Lingula*, was found by Miss E. C. Herdman, of Newnham College, Cambridge.

This little *Lingula* is but ·13 in., or $3\frac{1}{4}$ mm. in length, but by comparison of the pointed end (× 45) with that of the living *L. anatina*, it can, I think, be identified as a dorsal valve. Of course, we know that *Lingula* was living, somewhere, in Chalk times, but its remains seem usually to be found in deposits rich in terrigenous material, such as clays or sands, and so far as I can learn there are only two previous records of *Lingula* from the Chalk of the British Isles, (1) from the very bottom of the Lower Chalk, within 3 feet of the Upper Greensand, from the "Chloritic Marl" at Rye Hill Farm, 3 miles east of Maiden Bradley,[1] and (2) the beautiful small specimen in the Jermyn Street Museum, presented by Clement Reid, from the topmost (*Ostrea lunata*) zone of the Upper Chalk of Britain, from Trimingham.[2]

So anyone finding *Lingula*, however small, in the Chalk should carefully preserve and record it. We may thus perhaps learn something at once about *Lingula* and about the Chalk.

The salient feature of the collection made at this spot is the large number of *Baculites baculoides*. Some pieces of Chalk Marl, weighing as cleaned up only 2 oz., contain nine separate Baculite fragments! Some specimens of the later formed, obliquely ribbed, portion of the shell, show the slight curve that occurs near the aperture of the full grown shell; and other specimens of the earlier, smooth portion break across at the position of the septa.

Mantell[3] says that this Baculite occurs in the South Downs "in every marl pit of the S.E. part of Sussex". In the North Downs it is recorded[4] from this zone in the Medway cut; but otherwise I know of no previous record of it from this zone in the North Downs of Kent or Surrey, and making a special search myself from Betchworth to Reigate inclusive, the only place where I found *Baculites* in the *A. varians* zone is the small lower pit of the "Buckland Limeworks", and there comparatively few and poor specimens. I have, however, found *Baculites baculoides* in the "Melbourn Rock" both at Betchworth Pit and also at one of the small pits north-east of the exposure here described.

I failed to fix the onus of naming my "casts" on someone else, so the blame for the list must rest on me; but I should thank

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[1] Jukes-Browne and Scanes, Quart. Journ. Geol. Soc., vol. lvii, 1901, p. 117.

[2] Mem. Geol. Surv., *Cretaceous*, vol. iii, 1904, p. 482. [A small specimen from the *H. subglobosus* zone of Cherry Hinton has been found recently and is now in the Sedgwick Museum, Cambridge.—Ed. Geol. Mag.]

[3] *Fossils of the South Downs* . . . 1822, p. 123.

[4] Mem. Geol. Surv., *Cretaceous*, vol. ii, p. 50.

Mr. R. B. Newton, F.G.S., and Mr. H. A. Allen, F.G.S., for kind sympathy and facilities, and Professor G. A. J. Cole, F.R.S., and Mr. H. Woods, F.R.S., for kindly answering queries as to records of *Lingula* from the Chalk of Ireland and Britain respectively.

The Diatomaceous Earth of Lompoc, Santa Barbara Co., California.

By Sir NICHOLAS YERMOLOFF, K.C.B., K.C.V.O., F.L.S.; with a Prefatory Note by Dr. A. SMITH WOODWARD, F.R.S.

LAST year Mr. J. L. Bosqui gave to the Geological Department of the British Museum part of a fossil shoal of herrings found in a marine deposit of diatoms, now being worked for commercial purposes as "celite" in Santa Barbara Co., California. The species represented has since been named *Xyne grex* by Professors Jordan and Gilbert,[1] who exclude it from the genus *Clupea* on account of its thicker enamelled scales, enamelled opercular bones, and strong ventral scutes. The matrix, examined under the microscope, proved to consist so completely of diatoms and other siliceous organisms that it seemed desirable to submit them also to special examination. I was therefore fortunate in enlisting the services of Sir Nicholas Yermoloff, whose extended studies of such organisms make his determination and discussion of these new fossils of particular value. His notes form an interesting supplement to the following short account of the deposit, which was given by Dr. Frank M. Anderson to Professor Jordan (op. cit., p. 14):—

"The white shales about Shorb and El Modena are well known to be diatomaceous, and often considerable bodies of these rocks, that is a considerable thickness of them, is comparatively free from grit. I have been accustomed to regard these shales as of Puente age, as I believe they have been classified by Dr. Arnold, and I have been of the opinion that the Puente formation is middle or lower Miocene in age, and is the equivalent of the Monterey, taken in that sense.

"The Puente group is certainly not the base of the Miocene in the region about Los Angeles, and in the localities mentioned in your letter, namely Shorb and El Modena, the beds are near the middle or a little below the middle of the Miocene section.

"I presume you have some information regarding the large number of fossil fishes found in the diatomaceous beds of near the same horizon some 3 or 4 miles south of Lompoc, Santa Barbara County. The rock here is almost entirely made of diatom material some 600 to 800 feet thick.[2]

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[1] D. S. Jordan and J. Z. Gilbert, *Fossil Fishes of Southern California* (Leland Stanford Junior University Publications, University Series, 1919), p. 25, with figures.

[2] The maximum thickness was subsequently stated to be 1,400 feet by Jordan & Gilbert, *Fossil Fishes of the Diatom Beds of Lompoc, California* (loc. cit., 1920, p. 5).

"I believe that the diatoms, or the marine species of the Monterey group, are, or were, northern forms, and lived in the cooler waters of the North Pacific of the Miocene, and were brought south by the ocean currents of the time, and were trapped and impounded in such favourable places as were found along the Pacific coast of the period.

"Such favourable places were local, and more or less land-locked, or protected areas of the sea, free from sedimentation from the land, and where the surface waters of the sea were free to enter and escape, but where they were detained long enough to lose their contents of northern forms under conditions of temperature too high to permit their survival. It appears to me that the deposits of diatomaceous strata, as they are known in California, are all more or less local, and in their occurrence and distribution conform to this idea.

"I have also imagined that the climatic conditions of the coast in middle Miocene times were different from those before and after, for there is a well-known change in the character of the sediments of the Miocene, those of the middle being largely organic, and those of the lower and upper Miocene being generally coarse detrital matter in which the organic contents are inappreciable.

"It may be that physiographic changes in the continental border and in the ocean currents could have brought about these differences in sediments, but there are certain established facts that point to great climatic changes during Miocene times."—A. S. W.

The siliceous remains in the fossil deposit of Lompoc belong to two main and dominating groups of organisms, Dictyochideæ and Diatomaceæ. The deposit contains also a few Radiolaria, some siliceous sponge-spicules, and a few remains of *Lithasteriscus.*

The Dictyochideae are very numerous, in fact nearly as numerous as the Diatoms. This is remarkable and rather peculiar, because, although the genus *Dictyocha* has as a rule a very wide distribution, being present in nearly all fossil Diatomaceous deposits, yet it generally does not appear in other deposits in such dominating numbers as in Lompoc. Thus it is present in the fossil deposits of Richmond, Va., of Simbirsk, Mors, Oran, Oamaru, Sendai, and others; it is also observable in the Baltic (Kiel), and even in the Diatomaceous Oozes of the Antarctic Ocean as collected by H.M.S. *Challenger* at a depth of 1,950 fathoms. *Dictyocha* is, however, absent from the Polycystinous earths of Barbados.

In Lompoc *Dictyocha* is represented by three species, *Dictyocha gracilis* Ehr., *D. speculum* Ehr., and *D. fibula* Ehr. The first two species are abundant, but the third is rather scarce. *D. gracilis* Ehr. is also present in other Californian deposits, for instance, in Los Angeles; but it is much less numerous than in Lompoc.

The number of species of *Dictyocha,* as described by Kutzing, is about thirty-five. Some of the fossil deposits, such as those of

Simbirsk, Mors, and Oran, have species of their own; thus the Russian deposits of Simbirsk contain chiefly *Dictyocha triommata* Kutz.

Dictyocha,[1] a genus established by Ehrenberg, was for a long time thought to be a diatom; later it was included by Haeckel in the Radiolaria, but now it is proved to be a Silicoflagellate. Its species are distinguished mainly by their geometrical outlines and the number of horns, which vary greatly. The species *Dictyocha fibula* and *Dictyocha* (or *Distephanus*) *speculum* are living at the present day; as stated by Sir John Murray, they are met with in the plankton of North European coastal waters.

Besides *Dictyocha*, the Lompoc deposit contains also specimens of *Actiniscus Sirius* Ehr., but they are not dominating like those of *Dictyocha*.

The second main group of siliceous organisms in the Lompoc deposit is that of the diatoms. These are all pelagic and nearly all discoid, with only a very few gonoid forms. The Pseudo-Raphideæ are represented by several species of *Thalassionema*, also by *Raphoneis amphiceros*, var. *Californica*, and by a species of *Tabellaria*, which, however, is scarce. Of the so-called *Pleonemic* diatoms, only one species of *Chætoceros* has been found, namely *C. incurvum* Bail., but the deposit undoubtedly contains many rest-spores of *Chætoceros*, such as *Dicladia*, *Syndendrium*, and *Hercotheca*. The usual absence of *Chætoceros* and *Rhizosolenia* in fossil deposits is a fact which requires explanation, these genera being so common in planktons. Why, while so common and widely distributed, do their remains appear so rarely in the fossil deposits? Several explanations have been suggested. In the first place, *Chætoceros* and *Rhizosolenia* are very delicate organisms, easily destroyed by acids in the preparation of the slides. Secondly, they are neritic forms, thriving rather in coastal waters than in the high seas. Thirdly, it is an undoubted fact, that those diatoms which live in colonies and possess therefore special arrangements to augment their floating surfaces and floating capacities, rarely can fall down after death to the bottom of the ocean otherwise than as separate individuals. This is the reason why colonies of diatoms are, as a rule, so rarely met with in oozes and deposits in general. Indeed, it may be supposed that colonies of diatoms, even after death, continue to float about in the waters as dead plankton. No Raphideæ have been found in the Lompoc deposit, except one species of *Cocconeis*.

All the diatoms in Lompoc are undoubtedly northern forms; indeed, very similar to those usually common in European seas. A few more or less southern species have been observed, but they

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[1] An excellent monograph of the genus *Dictyocha* has been published by A. Borgert, "Über die Dictyochiden": Zeitsch. Wiss. Zool., Leipzig, vol. li, 1891.

are so scarce that their presence may perhaps be considered as accidental. Thus there are no *Arachnoidisci*, so common in warmer waters and present even in the Los Angeles deposit; only one *Coscinodiscus patellæformis* Grev. has been found, and no *Craspedodisci* have occurred. Only very few specimens of *Coscinodiscus bulliens* A. S. and *C. turgidus* Rattr., which are truly southern forms, have been observed. There are in Lompoc, it is true, many forms belonging to the group of *Coscinodiscus marginatus* Ehr., but the *marginatus* group can hardly be considered as strictly southern, this group being often met with, as in the Mediterranean Sea. On the other hand, Lompoc has very few representatives of the genus *Stephanopyxis*, or even of *Melosira*, species of which are common in warm waters. The genus *Actinocyclus* is entirely absent; on the other hand, one Actinocycloid form, namely *Euodia gibba* Bail., is not only abundant in Lompoc, but even dominating, just as it is equally frequent in the Moron deposit of Spain. The *Actinoptychus* forms in Lompoc are very poor; there are many specimens of *A. undulatus* Ehr., but they are nearly all of extremely small size, not exceeding some 30 microns. The genus *Asterolampra* is represented by two species, *A. Grevillei* Wallisch. and *A. rotula* Grev., both very frequent, just as they are frequent in the Mediterranean. The genus *Asteromphalus* is also represented by two species, *A. Moronensis* Rattr., common in the Moron deposit, and *A. Hookeri* Ehr., frequent in the Antarctic.

Together with *Dictyocha* and *Euodia*, the genus *Coscinodiscus* dominates in Lompoc. Indeed, these three genera share between them nearly the whole number of organisms in Lompoc.

Of the nine groups of the genus *Coscinodiscus*, as tabulated by Rattray in his "Revision", only five groups are represented in Lompoc. These five groups are the Inordinati, the Excentrici, the Lineati, the Fasciculati, and the Radiati. The four others, the Cestodiscoidales, the Eleganti, the Elaborati, and the Cocconeiformes, are absent.

Of the five groups present, the dominating one is that of the Radiati. This is made evident by the following statement of the respective numbers of species: Inordinati, 1 species; Excentrici, 3 species; Lineati, 8 species; Fasciculati, 13 species; Radiati, 25 species; total, 50 species. Besides these fifty species there are in Lompoc many intermediate transitional forms between the Excentrici and the Lineati, but their occurrence is not remarkable, because such transitional series are also observable in European seas.

A curious fact concerning the Fasciculati group is the following: *Coscinodiscus subtilis* Ehr. so common in European seas, is poorly represented in Lompoc by very few and small specimens; also, no so-called "derivatives" of *C. subtilis*, such as *C. Kutzingii* A. S., *C. Normani* Greg., and *C. Rothii* Grun., are to be found. It would appear as if the *subtilis* group had had no good opportunity to evolve in Lompoc. On the other hand, another branch of this same group, the *odontodiscus* branch, developed well and safely along two other branch-lines, the *odontophorus* branch and the *interlineatus* branch.

It is remarkable that in the Excentrici group Lompoc possesses the species known under the name of *Coscinodiscus decipiens* Grun., common in the Baltic.

We now turn to the analysis of the dominating Radiati group. Its *radiatus* subgroup, with its derivative *Coscinodiscus Argus* Ehr., is very numerous. The *oculis-iridis* subgroup is also very numerous with its large-sized derivative, *Coscinodiscus borealis* Bail. *Coscinodiscus centralis* Ehr. is also numerous, but, curiously enough, the closely allied *C. concinnus* W. Sm. and *C. nobilis* Grun., common in the Baltic and the Mediterranean, are totally absent.

The *marginatus* subgroup with its numerous derivatives, as shown in the appended list, is fairly numerous, though, as has been stated, this subgroup is already more or less transitional to southern forms. There are two interesting facts to note in its occurrence at Lompoc: in the first place there are many specimens of the so-called *C. robustus*, with exterior "springs" as described on p. 64 of Rattray's "Revision", and peculiar to the Californian Santa Monica deposit. In the second place there are some *Coscinodiscus* forms closely resembling tests of *Pxyidicula*, a genus sometimes considered to belong to the Rhizopods.

These forms have convex valves with punctuate alveoles. The punctæ on the alveoles are very clear and conspicuous. It is just possible that the forms mentioned in the appended list as *C. bipartitus* Rattr., or *C. blandus* A. S. may be tests of *Pyxidiculæ*, also perhaps *C. robustus* var. *fragilis* Rattr. The specimens from Lompoc classified as *C. bipartitus* are quite similar to the figures given by Professor De Toni in his work, *Analisi microscopica di alcuni saggi di fitoplankton raccolti dalla R.N. Liguria*, but they have no lobes, a circumstance hardly to be considered as unexpected, these lobes being of a non-siliceous composition and therefore not able to withstand the effects of fossilization. On the other hand, some of the forms in question rather resemble *Pyxidicula Mediterranea* Grun., a form not unfrequent in the Mediterranean Sea. The whole question is, however, as yet a subject of controversy requiring further elucidation.

A very curious fact in the Fasciculati group is exhibited in Lompoc in connexion with the species, *C. curvatulus* Ehr., *C. radiolatus* Ehr., *C. radiosus* Grun., *C. æginensis* A. S., and *C. nodulifer* Jan. All these species show something like a distinct nodule, whilst their fasciculate structures are extremely alike, the species passing from one to the other by most insensible gradations.

The genera *Dictyocha*, *Euodia*, *Coscinodiscus*, and *Thalassionema* dominate, and give to the deposit its characteristic facies. It has undoubtedly a much more northern facies than, say, the deposit from Los Angeles, which contains many more southern forms.

The abundance of the *Dictyocha* and *Euodia* is, indeed, the most remarkable feature in the Lompoc deposit.

As to the Radiolaria, the sponge-spicules, and the Lithasterisci, they are not by any means numerous and present no peculiarities. There are also no calcareous remains, such, for instance, as the plates of Holothurians, so well known in the Barbados earth. This is also an important fact, confirming the northern character of the Lompoc deposit.

List of Siliceous Organisms in the Fossil Deposit of Lompoc, Santa Barbara Co., California.

I. DICTYOCHIDEÆ.

Dictyocha.

gracilis Ehr. Abundant and dominating.
speculum Ehr. Abundant.
fibula Ehr. Rare.

Actiniscus.

Sirius Ehr. Frequent.

II. DIATOMACEÆ.

Euodia.

gibba Bail. Abundant and dominating.

Coscinodiscus.

(A) INORDINATI.

turgidus Rattr. Rare.

(B) CESTODISCOIDALES.

None.

(C) ELEGANTI.

None.

(D) ELABORATI.

None.

(E) COCCONEIFORMES.

None.

(F) EXCENTRICI.

excentricus Ehr. Abundant.
decipiens Grun. Frequent.
minor Ehr. Frequent.

Transitional forms to the Group Lineati:
Frequent.

(G) LINEATI.

lineatus Ehr. forma minor. Frequent.
lineatus Ehr. Frequent.
leptopus Grun. Frequent.
anguste-lineatus A. S. Frequent.
marginato-lineatus A. S. Frequent.
bipartitus Rattr. Without lobes. Frequent.
blandus A. S. Frequent.

(H) FASCICULATI.

(*a*) SUBTILIS GROUP.

subtilis Ehr. Rare. Small, poor specimens.
symbolophorus Grun. One specimen in nine slides.
odontophorus Grun. Frequent.
odontodiscus Grun. Frequent.
interlineatus Rattr. Not rare.
extravagans A. S. Not rare.
divisus Grun. Rare.
minutellus Rattr. Rare.

(*b*) CURVATULUS GROUP.

curvatulus Grun. Frequent.
nodulifer Jan. Frequent.
œginensis A. S. Frequent.
radiolatus Ehr. Frequent.
radiosus Ehr. Frequent.

(I) RADIATI.

(*a*) RADIATUS GROUP.

radiatus Ehr. Frequent.
Argus Ehr. Frequent.
obscurus A. S. Rare.

(*b*) OCULUS-IRIDIS GROUP.

oculus-iridis Ehr. Frequent.
borealis Ehr. Frequent.
asteromphalus Ehr. Rather rare.
centralis Ehr. Frequent.
perforatus Ehr. Not rare.
apiculatus Ehr. Not rare.

(*c*) HETEROPORUS GROUP.

heteroporus Ehr. Rare.
crassus Bail. Rare.
gigas Ehr. Frequent.
diorama A. S. Frequent.
bulliens A. S. Rare.
decrescens Grun. Rare.

(*d*) FIMBRIATUS GROUP.

fimbriatus Californica Grun. Frequent.

(*e*) MARGINATUS GROUP.

marginatus Ehr. Frequent.
robustus Grev. Frequent.
robustus bisculptus Rattr. Not rare.
robustus with "springs". Not rare. See p. 64 Rattray Revision.
robustus fragilis Rattr. Not rare. A *Pyxidicula* (?).

(*f*) OTHER RADIATI,

lunatus Grev.
velatus Ehr. Rare.
subvelatus Grun. Rare.
pectinatus Rattr. Frequent. Transitional.
subaulaco-discoidalis Rattr. Not rare.

Asterolampra.

Grevillei Wallisch. Frequent.
rotula Grev. Frequent.

Asteromphalus.

Moronensis Rattr. Frequent.
Hookeri Ehr. Frequent.

Actinoptychus.

undulatus Ehr. Frequent. Very small specimens.

Melosira.

sulcata biseriata.

Stephanogonia (Cladogramma).

Californica Grun. Not rare.

Chætoceros.

incurvum Bail. Rare.

REST-SPORES.

Dicladia.
Syndendrium.
Hercotheca mammillaris Ehr.
Other rest-spores.

Raphoneis.

amphiceros Californica. Frequent.

Thalassionema.

Nitzschioides Grun. Abundant.
Frauenfeldtii Grun. Abundant.

Biddulphia.

regina Wm. Sm. Rare.
Tuomeyii Bail. Rare.

Tabellaria.

Sp. (?)

Cocconeis.

Sp. (?)

REVIEWS.

VON BAU UND LEBEN DER TRILOBITEN. I. DAS SCHWIMMEN. II. DER AUFENTHALT AUF DEM BODEN. DER SCHUTZ. DIE ERNÄHRUNG. By RUDOLF RICHTER. *Senckenbergiana*, i, pp. 213–38, with 8 text-figures, December, 1919. ii, pp. 23–43, with 13 text-figures, February, 1920.

IN the new periodical *Senckenbergiana*, issued by the Museum of the Senckenberg Naturalists Society in Frankfurt a. M., Rudolf Richter has begun a series of interesting papers on the structure and life of Trilobites. Dr. Richter has been led to this by his studies of Devonian trilobites, and especially of the curious forms found at Gees near Gerolstein and developed with much skill by himself and others at the Senckenberg Museum.

Structurally fitted for a life on the sea-bottom, the trilobites frequently remained on the sea-floor, where they crawled on the ooze or on plants, or rested, either rolled up or outstretched and perhaps hidden by a thin layer of sediment. On the other hand, most, if not all, trilobites could swim by the aid of their many oar-like limbs. The smooth *Phacops–Proëtus* type, with its strong muscular body, was the most agile. The spiny or horned type, represented by *Cyphaspis*, *Acidaspis*, and above all the extraordinary *Lichas armatus* from Gees, was adapted for gentle movement and flotation or balancing in still water. Whether creeping or swimming, when disturbed they rolled up suddenly, and if swimming thus sank rapidly to the bottom. In the rolled-up state the spines, when present, are seen to surround the body.

When swimming the trilobites probably fed on larvæ and other minute organisms. When creeping they probably shovelled up the decaying fragments of plants and animals, being provided in many cases with shovels, ploughshares, or rakes. They did not, however, burrow deeply into the ooze, but kept on or just below the surface.

It will be seen that Dr. Richter's views do not entirely agree with those expressed by Walcott, Dollo, von Staff, and Reck, and others who have speculated on the subject. But they are maintained by ingenious arguments based on material both new and old.

F. A. B.

DOELTER'S HANDBUCH DER MINERALCHEMIE.

WE have received from the publishers four instalments of this work, which have appeared since 1914. From particulars given on the cover it appears that vol. i, both halves of vol. ii, and the first half of vol. iii are now complete. Of vol. iii there are now to hand parts v–vii. Part v includes a detailed description of a large number of arsenic and antimony minerals, mainly by Dr. H. Leitmeier, of Vienna, and Dr. Henglein, of Karlsruhe; part vi includes the minerals of bismuth and vanadium, and a long discussion of the chemistry and physics of water, by Dr. R. Kremann, of Graz, with title-page and index of vol. iii, first half; part vii commences the second half of vol. iii with the mineralogy of lithium, sodium, potassium, native copper and copper oxides, rubidium, and silver, also chiefly written by Dr. Leitmeier.

We are glad that it has been found possible to continue publication of this monumental work, which is of the greatest value from the amount of detailed information contained in it, as well as for the numerous references to the literature of modern mineralogy.

Manganese Ores. By A. H. Curtis. Imperial Institute Monographs on Mineral Resources. pp. 118. 1919. Price 3*s*. 6*d*. net.

THIS is an Imperial Institute publication which reflects credit on the author, who has prepared an interesting and useful monograph, as a result of an exhaustive study of all published information on the subject.

The War focussed attention on manganese ores, as the principal consumers drew their supplies from India, Caucasia, and Brazil, which necessitated ocean transport; and also because efforts to find an efficient substitute for manganese in the manufacture of steel were only partly successful.

Notwithstanding the high selling value of the mineral in recent years, few new deposits have been discovered. In Brazil, where the price incentive was perhaps greater than elsewhere, only one large ore body was found, which even now is not producing. In India no new developments have taken place, but the ferruginous deposits of the Sinai Peninsula, and those of the Gold Coast, both discovered shortly before the War, are now active producers.

The most striking development in the industry since 1914 took place in the United States, which not only intensively operated its own low-grade deposits, but also manufactured practically all its manganese-iron alloys, which in pre-War days had been largely imported from Europe, either in blast furnaces or by electric reduction.

In chapter I the author deals with the occurrence, character, and uses of manganese. It should be mentioned that the large Belgian imports of manganese ore prior to 1914 were principally used in Luxemburg and Germany. Further, the high manganese content of Caucasian mineral refers to the product of washing plants, which constitutes two-thirds of the total output, the "run of mine" being of inferior grade to the Brazilian and Indian ores which are not dressed.

It is interesting to record that the inability of the Caucasus and Brazil to increase their output in pre-War years was almost entirely due to the railways, on which the mineral was carried, being State-owned and operated, although in Russia there has always been the added disability due to labour unrest.

In chapter II useful tables are given regarding British imports and exports of manganese ore and ferro-alloys, and all Empire ore deposits are described, the details regarding the Indian deposits being obtained from the excellent Geological Survey publications. It may be mentioned that the lateritic deposits have proved to be highly ferruginous in depth, although in many cases of good grade at surface—suggesting precipitation of iron prior to manganese.

It is unfortunate that the comparison of costs of production of Brazilian, Russian, and Indian manganese ores is based on figures published many years ago. At the present time the cost of placing the mineral at British ports is probably the lowest for the Gold Coast and Sinai ores, followed by the Caucasian, Indian, and Brazilian supply, but conditions may change at any time, involving alteration in the order given.

Referring to the proposed manufacture of ferro-manganese in India, it may be noted that the alloy was produced at the Tata Works during the War, and in view of the rapid development of the Indian iron and steel industry, it is probable that it will continue to produce its requirements of ferro-alloys.

Mention is made of the utilization of manganese ore for the manufacture of pig-iron containing 2 per cent of manganese, which facilitates the removal of sulphur for basic steel manufacture. The estimated quantity so employed, however, viz. 50 per cent, is high ; a more correct figure would be 10 to 20 per cent, which, however, will be greater as the output of basic steel increases.

The South African deposits are not extensive, but may be developed for use in the local steel industry, and the same will probably obtain with both the Canadian and Australian ores.

The Gold Coast manganese ore deposits are important, and as it is probable others will be discovered in the same district, the Colony should become in the future an important source of supply. Successful dressing of the mineral, and the application of mechanical plant for getting and dressing the ore, as well as improvement of the shipping facilities, are necessary to ensure a largely increased export.

In chapter III the ore-bodies in foreign countries are described. It is interesting to note that the successful installation of washing plants in the Caucasus to treat the screenings, amounting to several million tons, accumulated since mining operations commenced, has resulted in a higher-grade product and prolonged the life of the deposit.

No mention is made of the Covadonga deposit in Northern Spain, probably because nothing has been published regarding it in recent years. Manganese and iron-ores occur as boulders, in a clay matrix resting on limestone, as the basement rock. The separation of the ore is effected mechanically, and three qualities of mineral are produced, viz. :—

(*a*) Manganese ore of the highest grade, almost free from phosphorus.

(*b*) Manganiferous iron-ore.
(*c*) Iron-ore.

The quantity of mineral existing is reported to be large, and the output in recent years has been appreciable.

The manganiferous deposits, mostly of low grade, in the United States, the output of which before 1914 was insignificant, produced in 1918, with the help of dressing plants, about half a million tons, containing upwards of 35 per cent manganese. The fall in the selling price of manganese ores, subsequent to the Armistice, caused the closing down of most of the deposits, but owing to the present scarcity of mineral and the high price obtained for it, it is probable that they will be again operated.

In the Lafayette Brazilian deposits at present worked, the alteration from carbonate to oxide continues in depth, but in a number of others originally spessartite the leached portion is shallow. As in India a number of deposits of the lateritic type have been similarly disappointing.

The volume would have been improved by some notes on the manufacture of manganese-iron alloys and a list of the firms engaged in their production.

UNITED STATES POTASH PRODUCTION.

POTASH IN 1917. By H. S. GALE and W. B. HICKS. Min. Res. United States, 1917, part ii, pp. 397–481. 1919.

DURING the year 1917 the shortage of potash due to the War reached its most acute stage, and it is therefore of particular interest to read in this interesting and valuable report the steps that were taken at that time, and the success which was achieved, in meeting the difficulty as it affected the United States. The following table summarizes the production during the year under review :—

Sources of Potash in the United States.	Total Production *Short tons.*	Available Potash, K_2O *Short tons.*
Natural brines	79,876	20,652
Kelp	11,306	3,572
Molasses residues from distilleries . . .	8,589	2,846
Alunite (refined salts and crude and roasted alunite)	7,153	2,402
Dust from cement-mills	13,582	1,621
Wood-ashes	1,035	621
Steffens water from sugar refineries . . .	2,642	369
Wool-washings and other industrial wastes .	645	305
Dust from blast furnaces	2,133	185

The report should be in the hands of all who are interested in the potash industry, for it includes not only a very full account of

American resources, actual and potential, but also a useful summary of foreign sources, accounts of the tests for potash, and processes of extraction, and finally a very full bibliography (up to and including 1918) of the whole subject.

ARTHUR HOLMES.

ORIGIN OF THE IRON ORES AT KIRUNA. By R. A. DALY. Vetenskapliga och praktiska Undersökningar i Lappland, Geology of the Kiruna District, part v. pp. 31, with 4 figures. Stockholm, 1915.

THE magnetite ore-bodies of Kirunavaara-Luossavaara are in some respects the finest known examples of the differentiation of oxides from an igneous magma, and there has naturally been a good deal of discussion as to the mechanism by which this has been brought about. Some writers consider the porphyries associated with the ores to be lava-flows, but Daly favours the hypothesis of intrusion. Emphasis is placed on the sequence of rock-types and on the chemical composition of the porphyries as confirmatory of magmatic segregation and particularly of the theory of differentiation in place. The ore-bodies are believed to be basic segregations from the overlying quartz-porphyry intrusion, the upper member of the composite laccolith, accumulated at its base by gravity; while the so-called "inclusions" found scattered throughout its whole thickness are also regarded as units of differentiation, and not xenoliths, as formerly believed. A detailed study of the forms of these masses favours this conclusion. Those masses scattered at higher levels are similar in composition to the ore-bed at the base, and are supposed to have crystallized after the magma had become too viscous to allow them to sink like the earlier ones which formed the ore. An important point is here raised, namely, that since no one disputes that single crystals, say of magnetite, in a magma are formed by differentiation, that is by aggregation of molecules from the solution, there is no reason why compound masses of greater size should not have been formed in an exactly analogous manner, and it is illogical to draw any arbitrary line between such units of varying size by assuming that the larger ones must be xenoliths.

R. H. R.

THE AMISK-ATHAPAPUSKOW LAKE DISTRICT. By E. L. BRUCE. Canada, Department of Mines, Geological Survey Memoir 105. pp. iii + 91, with 7 plates, 4 figures, and a coloured map. Ottawa, 1918.

THIS area lies on the boundary of Manitoba and Saskatchewan, on the divide between three great rivers, the Churchill, Nelson, and Saskatchewan. It forms part of the border of the Canadian shield, about half being occupied by pre-Cambrian rocks and half by Ordovician dolomites. The ancient rocks are divided into three series, the Amisk series of volcanic rocks at the base, followed by the Kisseynew gneisses; above these are the Lower and Upper Missi series, probably separated by an unconformity, and these are cut by gneissose granite. The main interest is economic, the minerals including gold-quartz veins and chalcopyrite-sphalerite replacements, both believed to be genetically related to the granite batholiths.

ON THE ORIGIN OF THE KUROKO OF THE KOSAKA COPPER MINE, NORTHERN JAPAN. By R. OHASHI. Journal of the Akita Mining College, 1920. pp. 11–18, with 2 figures and 2 plates. Akita, 1920.

KUROKO is a dense black ore consisting of sphalerite, galena, and barytes, usually with accessory pyrite, chalcopyrite, and quartz. Its formation has been attributed by most writers to metasomatism, but this explanation presents certain difficulties, especially from the absence of any sign of chemically active substances. The author, therefore, supports the theory of Fukuchi and Tsujimoto, that these deposits are masses of sinter deposited on the floor of the sea by hot springs, contemporaneously with the formation of the clay-beds in which they are now found; the springs were connected with the eruption of the interbedded rhyolites.

REPORTS AND PROCEEDINGS.

THE ROYAL SOCIETY.

April 29, 1920.—Sir J. J. Thomson, O.M., President, in the chair.

"The Irish Eskers." By Professor J. W. Gregory, F.R.S.

Eskers are banks of sand and gravel, typically occurring as ridges on the central plain of Ireland, where they were deposited during the recession of the ice at the close of the Glacial period. They have been generally attributed to deposition along glacial rivers, like Swedish *osar*. Their structure and composition indicate that the most important Irish eskers were formed along the margin of the receding ice-sheets by floods of water, due to the melting of the ice.

Irish eskers formed along glacial rivers are relatively small and exceptional. The accumulation of the materials into ridges, and their restriction between about 150 and 300 feet above sea-level, are attributed to the formation of the eskers where the ice entered into a sheet of water, which was probably the sea, since marine fossils are widely distributed in the adjacent drifts, and there are no embankments to maintain glacial lakes at the required level.

It is proposed that the term *esker* should be continued for Irish ridges and mounds of sand and gravel, but that in glacial geology the term *osar* should be used for ridges formed along the glacial rivers, and *kame* used for ridges deposited along the margin of an ice sheet.

GEOLOGISTS' ASSOCIATION.—*May* 7, 1920.

"Implements from Plateau Brick-earth at Ipswich." By Reginald A. Smith, F.S.A.

On the east side of Ipswich, immediately east of Derby Road Station, extensive excavations for brick-earth have brought to light a fine series of flint implements now in Miss Layard's collection at Christchurch Mansion, and described in Journ. R. Anthrop. Inst., xxxiii, 41; xxxiv, 306; xxxvi, 233. With the assistance of the Percy Sladen Trust, a large pit was dug under careful supervision in 1914, and the occurrence of worked flints at different levels verified. There had been 2 feet of contorted gravel above, and a sloping bank of gravel below, a wedge of brick-earth, suggesting the former presence of a river, which can, indeed, be deduced from the levels. Clement Reid recognized Boulder-clay at the bottom of a boring, at 27 feet, and the geology of the site has been studied by Professor Boswell (Proc. Geol. Assoc., xxv, 135), but a comparison with the Caddington Series (*Archeologia*, lxvii, 49) strengthens the argument for plateau deposits late in the palæolithic Drift period, and reopens the question of their relation to the Terrace gravels. The site is on an isolated part of the plateau between the main and lateral valleys of the Gipping and Deben, and is 120 feet above sea-level, the Boulder-clay terminating in an east-and-west line 1 mile to the north.

OPTICAL SOCIETY.—*April* 15, 1920.

"The Rock Crystal of Brazil." By R. R. Walls, M.A., B.Sc.

The author describes the occurrence in the field of the clear variety of quartz known as rock crystal. Although the high plateau of S.E. Brazil is essentially a granite and gneiss country, the rock crystal is not found in the granite itself, but in a series of bedded quartzites overlying the granite. Clear rock crystals occur only in the spaces between the bedding planes, but the planes of the crystals can be traced downwards for several feet across the bedding planes. Huge crystals have thus been formed, and the author illustrated one weighing 13 cwt. Clear crystal and coloured varieties—amethyst, smoky, and cairngorm—were found according to the purity or impurity of the original sandstone.

The sandstone had evidently been "stewed up" and metamorphosed into "crystal", but what was the cause of this is not clear. Intrusive granite suggested itself, but there was no sign of it anywhere. The crystal was found often in the neighbourhood of sericitic schist, which when worked out seemed to occupy a fissure in the horizontally bedded sandstones and quartzites. The sericitic schist contained diamonds, but was very evidently not an alluvial deposit. It appeared, therefore, as if this schist was the highly metamorphosed remains of a volcanic pipe similar to the diamond-bearing pipes of South Africa, and that its intrusion into the sandstones and quartzites had metamorphosed the latter into "crystal".

LIVERPOOL GEOLOGICAL SOCIETY.

April 13, 1920.—Mr. W. T. Walker, B.Sc., F.G.S., President, in the chair.

The following papers were read :—

1. " The Bellevale Borehole." By F. T. Maidwell, F.G.S.

The boring was made in 1919 by the Widnes Corporation for water at Bellevale, Little Woolton, close to the Liverpool city boundary, and reached a depth of 704 feet below the surface. Full details were given of the strata penetrated, which were almost entirely of Middle and Lower Bunter Sandstones.

2. " Coastal Changes at the Mouth of the Alt." By C. B. Travis.

The encroachments of the sea on the Cheshire and Lancashire coasts of the Mersey have attracted considerable attention during the past few months, and particularly on the northern shore of the estuary, where the spectacular feature of the menace of destruction of a number of fine detached residences at Hall Road has created much popular interest. The erosion which has taken place in the latter locality has been the subject of continuous detailed observations by Mr. Travis, who has carried out a series of surveys during the last twelve months dealing with the position of the River Alt on the foreshore, and of the changes of the high water-mark of the tides at various periods since 1893. Contrary to general supposition, the advance southward of the River Alt is no new feature, but brings part of the series of oscillations to which this river between Hightown and Waterloo has been subject over a very long period. By reproductions of old maps and charts, and recent surveys, the striking changes in the position of the outlet channels of the river during the last three centuries were illustrated, and it was shown that no periodicity can as yet be definitely established in relation to these fluctuations.

Details of the recent erosive effects and calculations of the loss of land suffered along this part of the South Lancashire coast, particularly during the past seven years, were given. The accretion of blown sand which has taken place along other parts of the same coast contemporaneously with the erosion was referred to, and the noteworthy gain of land by natural and artificial means in the neighbourhood of what is now the Altcar Rifle Range, and the formation and development of the salient of accretion known as Formby Point, since the seventeenth century, were described.

CORRESPONDENCE.

GAULT AND LOWER GREENSAND NEAR LEIGHTON BUZZARD.

SIR,—Although it would be easy to reply in detail to Mr. Lamplugh's letter on this subject, published in your issue of last month, we have no desire to do so. We are satisfied that a careful perusal of our recent paper provides the most convincing reply; and since our method of attacking the problem differs so widely from that adopted by Mr. Lamplugh, we feel that a controversy would be fruitless.

F. L. Kitchin.
J. Pringle.

London.
May 12, 1920.

Sir,—Although the subject of the Bournemouth Chines is chiefly of local interest, as Mr. Bury in his paper in the February number has referred several times to my views, may I be permitted a few words in reply?

Mr. Bury's paper chiefly deals with the seaward aspect of the chines, and curiously he omits mention of the one determining feature which is common to all the chines, and more than anything else is responsible for their form, depth, contour of sides, and angle of recession in cliff-face. This is the position, thickness, and number of the clay-beds which occur in the friable sandy strata from which the chines have been carved by the action of land water. In thirty years residence in the town I have more and more been struck by this, and led to attribute less and less to sea action at the cliff-face.

If any visitor will examine the shorter and lesser chines, such as Honeycombe Chine, east of Boscombe pier — which is not mentioned by Mr. Bury—also Middle Chine, Little Durley Chine, and Canford Cliff Chine, they will readily admit the influence of this factor. That the larger chines—Branksome, Bourne Valley, and the mouth of the Bourne, and probably Boscombe Chine—are remains of the old Solent River drainage system cannot be doubted. But all have been deepened and widened since the sea invaded Bournemouth Bay, by the action of land streams causing constant washing out of sand and slipping of clay-beds as they were uncovered.

I have never thought it necessary to invite the aid of glaciation or a hypothetical coombe-rock to account for what is otherwise easily explained. At the close of the Glacial period and the beginning of Neolithic times, floods from the melting of ice-sheets further north first eroded the surface and then deposited the sheet of plateau gravel which we find covering the strata around Bournemouth to-day. This occurred when the Bourne Valley was half its present depth. The plateau gravel is found in places down what Mr. Bury considers the old valley level in Branksome and Alum Chines. The present chine level has been formed since the close of the Glacial period. The Solent River system had been destroyed long before this, almost immediately on the sea breaking through the range of chalk hills which soundings show must have occurred not far east of Ballard Down, the period being either during or just before the raised beaches were formed.

With regard to the angle of the cliff-slope, my observations entirely confirm Mr. Carus Wilson's opinion that the cliffs are steeper now than formerly.

W. T. Ord, F.G.S.

Bramber,
18 Littledown Road,
Bournemouth, E.

NOMENCLATURE OF THE HEAVY LIQUIDS.

Sir,—In dealing with laboratory methods for the separation of minerals of different densities, some writers speak of Klein's solution, Brauns' solution, Rohrbach's solution, and Sonstadt's (or Thoulet's) solution. Others use the chemical names of the fluids—cadmium borotungstate, methylene iodide, etc. This double nomenclature is confusing and a tax on the memory, and it would be well if one or other set of names were adhered to and the other abandoned.

In the case of the double iodide solutions, the personal name has the advantage of brevity over the chemical. The desire to give honour where honour is due may also incline some workers to its use. But in this respect we are far from consistent. Bromoform, the most generally useful of all the heavy liquids, might with justice be called Schroeder van der Kolk's liquid. Moreover, Professor Brauns was not the discoverer of methylene iodide, he was merely the first to describe its application to mineralogy; and some of the other authors have even slighter claims to the liquids with which their names are associated.

The chief objection to the personal name is that it has no intrinsic relation to the fluid and suggests none of its properties. The chemical name, on the other hand, specifies the composition of the fluid referred to, and so recalls to mind its physical properties. The chemists will not be persuaded to call methylene iodide Brauns' solution, though they are not free from a similar practice (e.g. Fehling's solution, Condy's fluid, etc.). It would be a good thing if mineralogists would avoid the needless duplication of names and always use the chemical instead of the personal names for the heavy liquids.

G. M. Davies.

17 Elmwood Road, Croydon.
May 4, 1920.

OBITUARY.

Walter R. Billings.

Through the death of Mr. Walter R. Billings, Canada has lost a citizen of unusual attainments. His death occurred at his home in Ottawa on March 1, in his 71st year. Mr. Billings was an architect by profession and a palæontologist by natural taste and inclination.

Although palæontology was an avocation that he actively followed during only a portion of his mature life, the work which he has left forms a substantial and valuable contribution to the science.

The ancestry of Walter R. Billings on the paternal side was rather complex, including Welsh, English, Scotch, and Irish elements. His grandfather was born in Massachusetts, his grandmother in New York. Braddish Billings, grandfather of Walter, was the first white settler in Ottawa, where he came when there was nothing to suggest the future city, which developed later over a part of the 1,000 acre tract of land which he acquired. Walter R. Billings was a nephew of Elkanah Billings, the distinguished first palæontologist of the Canadian Geological Survey. To palæontologists the death of the nephew will recall the birthday of palæontological science in Canada, which may be said to coincide with the publication of Elkanah Billings' first paper on the Cystidea. To this able and remarkable man Canadian naturalists owe a debt of gratitude for starting at his own expense the first magazine devoted to Natural History published in Canada.

With such a sponsor in E. Billings, it is small wonder that palæontology made a strong appeal to the subject of this sketch. Inspired no doubt by the work of his uncle, Walter R. Billings became an ardent collector of fossils. That his collections came to include many rare and beautifully preserved specimens is sufficiently attested by the published references to them of foreign palæontologists. Dr. Bather, of the British Museum, has referred to many of the species collected by W. R. Billings. His generous spirit led him to loan his collections freely to those prepared to make use of them, and some of his rarest specimens were presented to the British Museum.

His own published studies were confined chiefly to the Crinoidea, and he is known to students of this group for his valuable work on the Trenton crinoidal fauna of Ontario.

Many important additions to the knowledge of the Crinoidea have been made by Dr. Bather from studies of material collected by W. R. Billings. He was always ready to place at the disposal of visiting geologists his intimate knowledge of collecting localities in the Ottawa district. The valuable collection of fossils left by him has been presented to the Canadian Geological Survey by his sisters, in accordance with his wishes.

He was a man of broad interests and for many years took a keen interest in athletics, especially in the water sports for which Ottawa is noted. Many of his vacations were spent on his luxuriously furnished house-boat. He represented a type of man far too rare in Canada, but more common in England, who finds the time and shows the ability to make worthy contributions to pure science while following a profession in no way allied to the science in which he delves.

E. M. Kindle.

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HENRY WOODWARD, LL.D., F.R.S.
AND
R. H. RASTALL, M.A.

JULY, 1920.

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THE

GEOLOGICAL MAGAZINE

VOLUME LVII.

No. VII.—JULY, 1920.

EDITORIAL NOTES.

OWING to pressure of original articles our Editorial Notes are this month considerably reduced in length.

* * * * * *

THE class list for the Second Part of the Natural Sciences Tripos, Cambridge, contains the names of two geologists who attained a first class: E. W. Ravenshear, M.C., M.A., Clare, and W. A. Macfadyen, B.A., St. John's. We believe these two gentlemen were the only geological candidates in the second part of the Tripos this year. The Harkness Scholarship is awarded to Mr. Ravenshear.

* * * * * *

MONSIEUR A. LACROIX, Member of the Institute and Professor of Mineralogy at the National Museum for Natural History, Paris, gave during the month of June four lectures at the Imperial College of Science (Royal School of Mines), South Kensington. The title of the course was announced as "Divers Modes de Dynamisme des Eruptions Volcaniques: Phénomènes de Lateritization". The lectures were delivered in French, and illustrated by numerous lantern slides. Sir Jethro J. H. Teall took the chair, and the course was attended by a considerable audience of petrologists and advanced students of geology.

* * * * * *

WE have received a copy of an interesting paper read by Dr. A. W. Rogers, F.R.S., to the Chemical, Metallurgical, and Mining Society of South Africa on the identification of the mineral character of particles in mine dust by the application of petrological methods. By an ingenious application of the well-known Becke bright-line method Dr. Rogers has been able to identify particles of quartz down to less than one micron in diameter. The importance of this is obvious, in view of the injurious properties of quartz dust in the air breathed by miners. In the discussion on this paper one speaker expressed surprise that any practical result should have followed consultation with a geologist. Now the fact is that geology is such a wide subject and deals with so many sides of science that there are few matters of a physical kind on which a geologist has not something to say, generally very much to the point. This was abundantly proved during the War.

ORIGINAL ARTICLES.

Differentiation and Ore-deposits.

By R. H. Rastall, M.A., F.G.S., University Lecturer in Economic Geology, Cambridge.

AT the present time most mining geologists appear to be in general agreement on the principle that primary ore-deposits are derived from igneous magmas. Furthermore, it is now almost universally recognized that the segregation and concentration of the metals and their compounds into payable ore-deposits is but part of a larger and more fundamental problem, namely, the differentiation of the igneous rocks, a problem which has exercised the ingenuity of petrologists for many years past and is still by no means solved. Unfortunately most of the speculations and theories put forward in explanation of these phenomena are in the main founded on facts and inferences derived from the study of the silicates; comparatively few petrologists have taken into account the behaviour of the oxidic and sulphidic compounds of the useful metals, which are commonly regarded in the light of rare and accidental constituents of the magma, rather than as having any particular bearing on the point at issue. The most notable exception to this general statement is Vogt,[1] whose work on slags and ore-deposits is of an epoch-making character from the theoretical point of view, as well as of immense practical importance in smelting and blast-furnace practice. However, within the last few years great attention has been devoted by mining geologists to the subject of the genesis of ore-deposits, mainly because of its bearing on the question of persistence in depth or the replacement at lower levels of one ore by another, such as is known to occur in certain cases. It may be suggested, therefore, that the time has now come when it may be possible to attempt to combine the facts hitherto discovered along different lines of research into a coherent whole.

We have stated that most mining geologists are in agreement as to the derivation of primary ores from magmas, but there is still a good deal of difference of opinion as to the nature of the processes by which this derivation or segregation is brought about. The most unfortunate feature of the whole problem is that investigation by experiment is almost, if not quite, impossible; it is unlikely that we shall ever be able to realize in our laboratories the temperatures and pressures that must prevail at even small depths in the earth's crust, small, that is, by comparison with the radius, though large when expressed in feet or miles. It is necessary, therefore, to fall back on indirect evidence and arguments from analogy, and it must be admitted frankly that extrapolation is always a dangerous process.

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[1] *Studier over Slagger*, Stockholm, 1884; *Die Silikatschmelzlösungen*, Kristiania, 1903–4.

As we have already stated, much difference of opinion has prevailed and still continues to prevail among petrologists as to the real nature of the processes by which differentiation of rock-magmas has been brought about. From our point of view the elucidation of the exact mechanism of the processes involved is of less importance than a clear recognition of the fact that differentiation has taken place. Here it is necessary to consider for a moment what we really mean by differentiation. As a matter of fact two distinct ideas are here involved, namely, (*a*) the production of heterogeneity within the limits of a single continuous mass, and (*b*) the splitting of an originally homogeneous mass into two or more separate and discrete portions.[1] It may be regarded as certain that both of these effects have been produced in different ways in different cases.

Theories of differentiation may be divided into three principal categories, as follows: (1) differentiation by sinking of crystals in a liquid magma, (2) differentiation by diffusion of molecules in solution to the marginal portions of a cooling and crystallizing mass, (3) separation of a solution into two immiscible fractions as temperature falls. It will be observed that (1) and (2) are very similar, while (3) is essentially different, in that its occurrence may be long antecedent to solidification. Hence we see that there are really two types of differentiation, one depending on solidification (crystallization), the other being entirely independent of it. Another point which has led to much discussion is this, whether any form of differentiation is dependent on assimilation of rock from the walls of the magma-basin. This hypothesis of the production of heterogeneous differentiation products by absorption of material acting as a flux has been largely developed by Loewinson-Lessing[2] and by Daly.[3] Both of these authors consider that there were two primary magmas, granitic and basaltic respectively, and Daly regards the alkaline rocks, the syenites and trachytes and their congeners, as formed by differentiation from the primary granitic magma after assimilation of limestone. To this process he applies the name *syntexis*. Neither author has apparently considered the origin of the two primary magmas from a still earlier common source, a possibility which must also be taken into account in a complete theory.

It will, I think, be generally agreed that in a case of this kind the best method of procedure is to start from a foundation of known facts and work back to the unknown. Let us, therefore, begin with

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[1] It has been well pointed out by Daly that the formation of crystals of different minerals, such as quartz, felspar, and mica, from a magmatic solution is in reality a process of differentiation in its simplest form. Each single crystal is in such a case a unit of differentiation. This point has been ignored by most petrologists. It is in reality only the mono-mineralic rocks which can be regarded as strictly homogeneous, and these are very rare.

[2] Loewinson-Lessing, GEOL. MAG., 1911, p. 248.

[3] Daly, *Igneous Rocks and their Origin*, New York, 1914.

a simple case on which we possess some solid information as a basis. In the smelting of metals from their ores the metal sinks to the bottom, while the non-metallic impurities and fluxes rise to the top as a slag. This is not merely sinking by gravity, but depends on the principle of immiscible liquids. Vogt has shown that at any given temperature above the freezing-point of both liquids there is a certain amount of mutual solution, the metal dissolving some of the slag and the slag dissolving some of the metal, and that the solubility in each fraction increases with the temperature. It may be inferred, therefore, that at a certain very high temperature there would be complete mutual solubility in any proportions. Such temperatures have not, however, been attained in ordinary furnace practice. Now, if we invert the argument and imagine a rock-magma consisting of mutually dissolved silicates and sulphides at a very high temperature, but constantly losing heat by conduction, a time will come when the magma must begin to separate into two layers, one rich in silicates, the other in sulphides, and the sulphide portion being the heavier will occupy a lower position, thus leading to a segregation of sulphides at the bottom of the magma basin. In other instances the metals may be present as oxides or fluorides, instead of sulphides, but the result will be the same, namely, a stratification of the magma. It is possible that in some cases the metallic compounds may be lighter than the silicates, and therefore form the upper layer, but the principle is the same. The amount of one of the constituents present in the rock formed from the other fraction when solidified, e.g. the amount of sulphide in normal gabbro or norite, will depend on the solubility of the sulphide in the gabbro magma at its temperature of consolidation. Therefore, it would appear that there must be a limit to the percentage of primary ore that can occur evenly disseminated throughout a rock mass. If the amount of metal was originally in excess of this proportion it would necessarily form a richer segregation layer at the bottom. The foregoing statement represents what must occur in the simplest possible case. When the metals form volatile compounds the relations are more complex, as will be explained in a later section.

The argument may now be carried one stage further back. It has been suggested by certain leading petrologists that some of the phenomena of differentiation, as shown by the distribution of varying rock-types in definite areas, can be explained on the supposition of limited miscibility between magmas of different silica percentage, or in other words between acid and basic magmas. The general idea is that with a falling temperature the silicates of magnesia, iron, and lime become less soluble in the silicates of alumina, potash, and soda, and a separation occurs, the silica dividing itself in the proper ratio between the two fractions, thus producing two partial magmas. The magnesia, iron, and lime require less silica for complete normal saturation than the alumina, potash, and soda, hence one fraction is a basic magma, the other an acid one, in the ordinary sense. The basic magma is of higher density and therefore sinks to the lower level.

With regard to the metallic constituents, sulphides and oxides, it is evident that they will tend to distribute themselves also between the two partial magmas in the ratios of their solubilities. From the association of particular metals with definite rock-types it may be concluded that some metals are more soluble in the acid fraction, some in the basic, while others appear to occur in both. Thus, copper and iron, for example, are found in igneous rocks of almost all types, tin, tungsten, and molybdenum are definitely associated with granites, while nickel, chromium, and platinum belong to basic and ultrabasic types. When the temperature falls still further a similar process will take place with regard to the metallic constituents dissolved in each partial magma, and the oxidic and sulphidic ores will separate out in each case as immiscible layers, as before outlined.

Now it is clear that this principle is capable of almost indefinite extension; when the temperature is high enough we may conclude that all substances, whether silicates, sulphides, oxides, fluorides, borides, tungstates, or anything else, may become mutually soluble, i.e. miscible in all proportions, therefore the deeper we descend into the earth the more generalized should we expect the rock-types to become, and the more evenly distributed the metallic compounds. It is obvious, however, that the lowest levels attainable by artificial means or the depth of formation of most deep-seated rocks brought up by geological disturbances of mountain-building and faulting, are but trifling in comparison with the radius of the earth.

It may be objected that the known varieties of igneous rocks are too numerous and complicated to have been formed in this simple way, but it has been effectively shown by Daly[1] that by far the greater number of rock-types are rare and local, forming but a minute fraction of the total. For example, he shows that in North America the much-talked-of alkaline group (syenites, etc.) constitute only about 0·1 per cent of the total, and in other parts of the world they are not much more abundant.[1] In fact, it can be maintained, probably with truth, that the vast majority of the rock-types to which special names have been applied are due to local circumstances, such as assimilation of limestone and similar fluxing material, giving rise to special and peculiar chemical and physical processes within the magmas. Daly considers that there are but two fundamental magmas, the granitic and the basaltic, and of these he is inclined to regard the basic or basaltic magma as the most primitive. This is in conformity with the high density of the earth as a whole.

We therefore picture the evolution of the primitive homogeneous earth-magma as a process of differential splitting into successive fractions owing to a progressive decrease of mutual solubility with fall of temperature. The exact nature of the process giving rise to

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[1] R. A. Daly, *Igneous Rocks and their Origin*, New York, 1914, p. 47.

the splitting is a matter of minor importance; the facts of nature and the distribution of the varying rock-types are in themselves sufficient proof that something of the sort must have occurred, however it was brought about. It is unnecessary here to consider in detail the means by which the differential fractions have become isolated in separate basins within the earth's crust, or poured out as extrusions at the surface (lava-flows). This part of the subject has been discussed in detail by many writers. What we are mainly concerned with now is the ultimate fate of the metallic constituents that were dissolved in the differentiated partial magmas before solidification began.

Let us first consider the case of a granite magma, such as the granites of Cornwall, into which has been carried during partition a considerable proportion of tin, tungsten, copper, arsenic, lead, zinc, and other metals, together with fluorine, boron, and water, in addition to the constituents of the silicates, felspar, and mica, together with an excess of silica. The micas crystallize first, followed by the felspars, in the order of their freezing-points; these are followed by quartz, the metallic constituents, together with the fluorine, boron, and water, all tending to concentrate in the last unfrozen residue, presumably in the middle and lower parts of the mass, which are the hottest. All these probably remain unsolidified to a comparatively low temperature, perhaps below a visible red heat, although it must be remembered that pressure raises freezing-points. However, the already solidified mass is still cooling and therefore shrinking in volume. Consequently cracks must be developed to relieve the strain. These cracks apparently often extended radially into the surrounding rocks. Along these cracks the still fluid material from the interior must shoot out, under high pressure due to superheated water, filling them with the residual magmatic material, and in the process also bringing about far-reaching chemical changes in the wall-rock of the fissures. Thus we account for the pegmatites, aplites, and greisens, so common in and around many highly mineralized granites. In some cases also the escape of fluids from the cooling magma has been facilitated by earth movements, inducing fissure systems dependent on the direction of these movements, rather than merely radial. Sometimes the active chemical agents derived from the magma bring about the most far-reaching changes, such as tourmalinization, in the granite itself, the extreme case being schorl-rock, where everything has been converted to quartz and tourmaline; in other instances topaz is very abundant.

But the point of immediate interest is the fate of the metallic compounds in the magma. We know from incontrovertible evidence that the deposition of the ores belongs to the later stages of magmatic cooling. There is no need to labour this point. It may be taken as demonstrated that the deposition of the ores is subsequent to the crystallization of the main mass, and many of them are found in the pegmatites and greisens, having been deposited contemporaneously with their formation. But the question of the quartz-veins in the stricter sense of the word requires a little more detailed consideration. In the first place it should be remembered that the processes here under review take place at temperatures above the critical point of water, 365 degrees C., and therefore the usual distinction between liquid and vapour is then non-existent. For this reason the term fluid has been used throughout this discussion. We do not know the temperatures at which the normal quartz-felspar pegmatites actually solidify, but we do know that they often contain ore-minerals. Some ore-minerals therefore form at fairly high temperatures. There is now abundant evidence from observation that many true pegmatites pass by insensible transitions, by diminution of felspar, mica, etc., and corresponding increase of quartz, into quartz-veins in the ordinary sense of the term, either with or without metallic minerals. In some cases a vein may be a pegmatite within the granite, passing gradually into a quartz vein in the sediments. It is clear, therefore, that there is no real distinction between these two types.

It is necessary next to inquire why some of the constituents of the original magma should remain liquid so much longer, i.e. to a lower temperature than the main mass. The answer to this question is to be found in a consideration of the effect of the more volatile substances contained in the original magma. As this gradually solidifies it is obvious that all the substances of lowest freezing-point must tend to concentrate in the last fluid residue. Among these substances are to be reckoned compounds of the useful metals. These probably exist in the magma as fluorides, borides, sulphides, and hydrates. The presence of superheated water here is doubtless of first-class importance, as shown by Arrhenius.[1] For example, tungsten fluoride is known to be a gas at the ordinary temperature, while tin fluoride boils at 705 degrees C.[2] As the temperature falls these elements group themselves differently and eventually crystallize out as metallic minerals, together with the silica of the residual magma, which crystallizes as one of the two forms of quartz. The last fraction of all is a pure, or nearly pure, solution of silica, which forms the simple quartz-veins often found far from the margin of any visible intrusion. It appears clear, therefore, that there is no real line of demarcation between the so-called pegmatitic and hydrothermal mineral deposits.

When several metals are present in one individual magma, as is usually the case, each will form a compound having its own solidification temperature and therefore capable of travelling only as far as the corresponding temperature extends into the surrounding rocks; we shall therefore have a series of ore-zones around the intrusion, as is so well seen in Cornwall.

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[1] "Zur Physik des Vulkanismus": Geol. Foren. Forh., vol. xxii, 1900, 395. Abstract in GEOL. MAG., 1907, p. 173.

[2] Roscoe & Schorlemmer, *Treatise on Chemistry*, vol. ii, 1913, pp. 861, 1095.

Thus it is obvious that when a partial magma has reached its final resting-place and is there crystallizing, there must be a more or less complete separation of metallic constituents. This takes place in two stages, first a concentration in the last residue of the crystallizing magma, and then a translation along with this residue into dykes, veins, and lodes.

This process is best known and the relations are most clear in the case of the acid magmas, but the same thing occurs in the case of basic intrusions, with one important difference. The basic magma is less rich in volatile constituents, fluorine and boron being absent, and for some reason not yet understood water is apparently less abundant. Hence there is less tendency for the metals to segregate into dykes and veins. More commonly they remain more or less evenly disseminated like chromium and platinum, or sink to the bottom like the nickeliferous sulphides. It is worth noting that chromium and platinum are most abundant in the ultrabasic peridotites, which are themselves to be regarded as differentiates of the larger basic magmas.

We are thus led to recognize two distinct types of ore-deposits of direct magmatic origin, formed by differentiation, namely, the segregations within the mass of the magma itself, such as the nickeliferous sulphides of Sudbury or the iron-ores of Kirunavaara, where there has been only separation by sinking within the basin, and secondly, the fissure deposits, dykes, and veins, formed by translation of metalliferous portions, usually upwards or laterally, and frequently extending beyond the boundaries of the basin; the clearest examples of this type are afforded by the tin and tungsten deposits, while a similar origin may be postulated for a great number of other metallic ores, including copper, lead, zinc, arsenic, antimony, bismuth, mercury, silver, and gold. It appears probable that as a result of extended study it will become possible to draw up further generalizations, by assigning each metal or group of metals to its own petrographic rock-type. Thus it appears that gold is specially characteristic of the monzonite group, while the rare earths are concentrated into highly alkaline partial magmas.

With regard to the actual mechanism of differentiation, the subject of so much discussion of late years among petrologists, the matter is of minor importance; it is the effects with which we are really concerned. All the facts go to show that some sort of splitting of magmas must have occurred; the question of how or why is mainly of academic interest. The chief battle at present is between the advocates of differentiation by diffusion *before* formation of solid crystals, and differentiation by gravity *after* the crystals are formed, while the immiscible liquid theory comes in a bad third. Now it is obvious that partial magmas which are still liquid after the differentiation cannot have been formed by sinking of solid crystals, or, at any rate, both fractions cannot. The upper fraction might, of course, become impoverished in certain constituents by sinking of crystals, but not the lower. Now there is evidence that during their final crystallization some intrusions have become stratified by gravitational sinking, as in the Palisade Traps of New York and New Jersey, where the lower layers are very rich in olivine and other heavy basic silicates, while the upper part of the sheet has almost the composition of a granite, and yet there are no lines of demarcation, but a gradual transition throughout.

On the other hand, there is evidence that metallic compounds tend to accumulate in the upper portions of granitic masses. In the great granitic bathyliths of Western America it has been described how the mineralization is concentrated in the upper portions of the minor domes or cupolas that diversify the general surface of the intrusion;[1] this is obviously due to a gravitational rising of the metalliferous fluids into the upper portions of the granite. It is immaterial whether this occurred before or after the general solidification of the rock.

Hitherto we have spoken mainly of ore-deposits occurring in definite dykes and veins or of segregations within or at the base of igneous masses. There yet remain other important classes, such as the brecciated lodes and the endless varieties of so-called contact and replacement deposits. It is not proposed to discuss at length the genesis of these. The lode-deposits of the type here indicated can be explained on essentially similar principles: vapours or solutions differentiated from igneous magmas penetrate into zones or belts of fractured rock, of the type commonly now described as "shatter belts". Various more or less far-reaching chemical changes were induced in the minerals of the country rock, while the constituents of the solutions were deposited as ore and gangue minerals in the interstitial spaces. Such lode-deposits often show no definite boundaries, but shade off gradually into the unaltered country rock. On the other hand, most of the replacement and contact deposits come under the petrological category of metasomatism, a special type of metamorphism involving a change in the total bulk-composition of the rock. This is a large subject, needing extended treatment, which cannot be followed further at this time. The point to be emphasized, however, is this, that the fluids giving rise to these types of lode-formation, contact, and replacement deposits are of the same nature and origin as those that have filled the sharply defined metalliferous veins, all being derived from igneous magmas. Of course, it is not here maintained that *all* ore-deposits are of direct igneous origin; doubtless there are many exceptions, but the evidence at present available goes to show that a vast number are so. Also no account is here taken of the highly important changes induced by oxidation, leaching, and secondary deposition. Only primary unoxidized ores are specifically referred to.

In the accompanying diagram an attempt is made to

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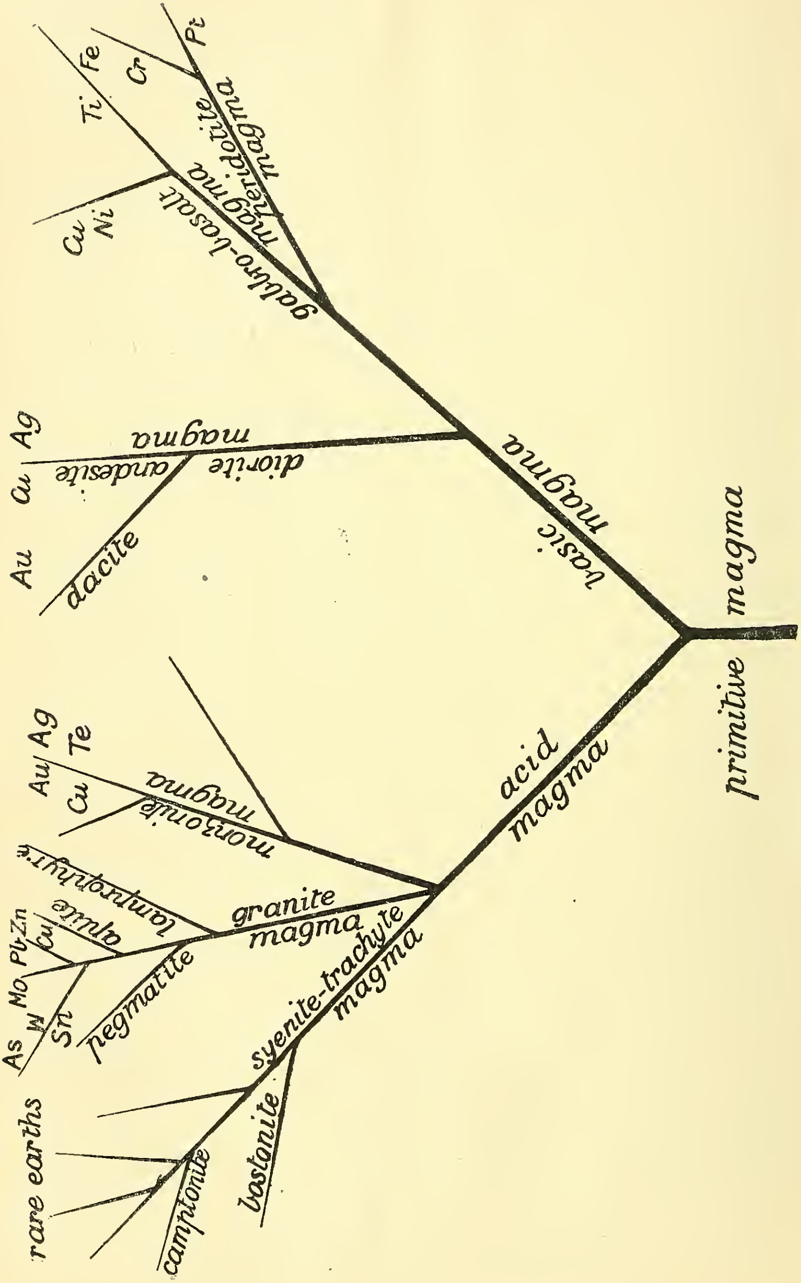
[1] Butler, *Econ. Geol.*, vol. x, 1915, pp. 101–22.



Genealogical tree of the differentiated ore-deposits.

summarize in a graphic form the ideas here put forward and to construct a genealogical tree of the igneous rocks and their related ore-deposits, tracing their descent by successive steps from a hypothetical primitive magma, through various stages of differentiation to the innumerable and varied types that we see to-day. This must be regarded, however, as merely an attempt, and must not be taken too literally, since the data available are as yet insufficient for dogmatism on many points. As already stated the whole question of the actual physical mechanism of differentiation is still *sub judice* ; between the diverse opinions expressed by eminent authorities it is as yet too early to decide. The fact remains that some sort of splitting of rock-solutions must have occurred ; that is not disputed by any one, but it is improbable that we shall ever be in a position to state exactly what has happened in every case. Nevertheless, it is clear that these processes, whatever they were, have been the dominant factor in the origin and primary distribution of the deposits of the useful metals on which so much of the world's industrial development depends.

Notes on the Fauna of the Lower Devonian Beds of Torquay.

By F. R. Cowper Reed, Sc.D., F.G.S.

Part I.

(PLATE IV.)

Introductory Remarks.

OUR knowledge of the fauna contained in the Lower Devonian beds of England is extremely imperfect and unsatisfactory, partly owing to the scantiness of the material which has been collected, and partly to the poor preservation of most of the fossils themselves. The lists of genera and species given in the Survey memoir (Explan. Sheet 350) dealing with the Torquay district are not extensive, and in many cases the determination of the species or even the genera is open to doubt. Correlation in detail with the well-established and richly fossiliferous Lower Devonian of the Continent is almost impossible in such circumstances, but Kayser in 1889, on the strength of the palæontological evidence which he obtained on the spot, correlated the beds at Meadfoot with the Lower Coblenzian.[1] The fossils which he collected and identified from this locality were the following Rhenish species: *Zaphrentis oolitica*, *Rhynchonella daleidensis*, *Chonetes sarcinulata*, *Spirifera hysterica*, *Sp. paradoxa*, *Strophomena* cf. *Murchisoni*, *Pterinea costata*.

Classification of the Lower Devonian Beds of Torquay.

The division of the Lower Devonian of the Torquay district into a lower portion termed the "Meadfoot Beds" and an upper portion

[1] Kayser, Neues Jahrb. f. Min. Geol., 1889, i, p. 188.

termed the "Staddon Grits" is adopted in the Geological Survey memoir (Explan. Sheet 350, 1903), the basal group of the Lower Devonian, the "Dartmouth Slates", being considered to be unrepresented there. The boundary between the Meadfoot Beds and Staddon Grits is not satisfactorily fixed, but the two principal exposures which have yielded most of the fossils here described are respectively near Kilmorie House, in Meadfoot Bay, and in the New Cut, on the Lincombe Drive. The lithological characters of the beds at these two localities as well as the contained faunas are sufficiently distinct. The red fossiliferous beds at Smugglers' Cove differ somewhat in lithological characters from those of the New Cut, and contain a different assemblage of fossils, so far as the scanty fauna is known, but they are ascribed to the Staddon Grits in the above-mentioned memoir of the Geological Survey.

Undoubtedly there is much scope for further systematic collecting of fossils from these beds, and though the specimens are as a rule poorly preserved or fragmentary, yet they frequently admit of specific identification when studied alongside of better material from the Continent.

The collections in the Sedgwick Museum, Cambridge, have supplied most of the specimens on which the following notes are based, but the Lower Devonian fossils in the Torquay Museum, the Jermyn Street Museum, and the British Museum have also been examined, and my thanks are due to Mr. Harford Lowe, Dr. Kitchin, and others for much assistance in my work.

Previous Literature.

A large number of fossils were described or recorded by Phillips in his *Palæozoic Fossils of Cornwall and Devon* (1841) from "Meadsfoot" or "Meadsfoot Sands", but only in some cases (marked * in the following list) have the original specimens been traced, and with regard to the remainder of the types some doubt exists. The names following in brackets are those used in the present article.

**Pleurodictyum problematicum* Goldf.
**Nucula ovata* Sow. (= *Cleidophorus subovatus* sp. nov.).
**Avicula anisota* Phill. (= *Pterinea anisota*).
**Orthis sordida* Phill. (= *Chonetes plebeia* Schnur).
O. plicata Sow. 1840 (not *O. plicata* Sow., Davidson, Mon. Brit. Foss. Brach., iii, p. 245).
O. granulosa Phill. (genus doubtful).
Spirifera costata Sow. (? = *S. subcuspidatus*).
Euomphalus serpens Phill.
**Bellerophon trilobatus* Sow. (= *Bucaniella* sp.).
Orthoceras tentaculare Phill.
**Homalonotus* sp. (? = *H. armatus* Burm. ?).

Etheridge, sen., in 1867[1] recorded the following Lower Devonian species from South Devon, but whether all came from the Torquay district is uncertain, as is also the accuracy of the identifications.

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[1] Etheridge, Quart. Journ. Geol. Soc., vol. xxiii, 1867, pp. 579, 619–25, 636.

Aviculopecten polytrichus Phill.
Pterinea anisota Phill.
Clidophorus ovatus Sow. (= *C. subovatus* sp. nov.).
Athyris concentrica v. Buch.
Leptæna laticosta Conr. (= *Trop. rhenanus* Frech).
Orthis granulosa Phill.
Orthis (?) *hipparionyx* Vanux.
Rhynchonella cuboides Sow.
Homalonotus Herscheli Murch. (?).
H. armatus Burm.

Tawney[1] in 1870 gave a list of fossils from the "red grits" of Smugglers' Cove. *Tentaculites scalaris* is said to be most abundant, and the following species are also recorded :—

Cypricardia lamellosa (?).
Pterinea ventricosa (?).
,, (like *bifida* or *anisota*).
Orthis arcuata (?).
,, (like *Berthoisi*).
Streptorhynchus gigas.
Homalonotus (like *Johannis*).

Several other molluscan genera are mentioned without specific names, but the whole list is characterized by uncertainty as to the identifications. Davidson[2] in his monograph mentions only the following brachiopods from the Lower Devonian rocks of Meadfoot, nearly all his recorded and figured species coming from the North Devon beds of this age.

Spirifera undifera.
,, ,, var. *undulata.*
Rhynchonella cuboides (Sow.).
Leptæna laticosta Conr.

In 1881 Woodward[3] published a list of fossils (determined by Etheridge) from the Red Beds of New Cut, in connexion with his description of the species *Homalonotus Champernownei*, but only three of them were specifically identified (*Rhynchonella pengellyana* ? *Streptorhynchus umbraculum*, and *Pleurodictyum problematicum*), the others having only generic names assigned to them. It is of interest to note that *Cyrtoceras* and *Orthoceras* are given in the list, for cephalopods seem as a rule extremely rare in this district.

In 1882 Etheridge[4] described and figured several species from New Cut and Smugglers' Cove, and thus added considerably to our knowledge of the fauna, though the present author is inclined to differ from some of his determinations in the light of further material.

Cypricardia lævisulcus Ether. (= *Tellinites lævisulcus*).
Modiolopsis sp.
Spirifera cultrijugata Röm. (?) (= *Orthis provulvaria* Maur.).
Rhynchonella laticosta Dav. (?) (? = *Tropid. rhenanus* Frech).
Orthis hipparionix vel *O. striatula* (= *O. provulvaria* Maur.).
Chonetes sordida (Phill.) (= *Ch. plebeia* Schnur).
Loxonema (?) sp.

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[1] Tawney, Rep. Devon Assoc., vol. iv, pt. i, 1870, p. 291.
[2] Davidson, Mon. Brit. Foss. Brach., vol. iii, Devonian (*passim*).
[3] Woodward, Geol. Mag., 1881, pp. 489, 528, Pl. XIII.
[4] Etheridge, ibid., 1882, p. 154, pl. iv.

Woodward[1] at the same time described and figured a new species, *Homalonotus goniopygæus*, from Smugglers' Cove, and a pygidium which he attributed to *H. Champernownei.*

In 1901 Whidborne[2] described some supposed Lower Devonian fossils from the site of the Pengelly Memorial Hall, Torquay, but Messrs. Jukes-Browne and R. B. Newton[3] subsequently disputed the accuracy of his determinations and regarded the fauna as indicating Middle Devonian beds. With the latter conclusion the present author is compelled to agree.

Note.—In the following descriptions of the species the letter S. denotes that the specimen is in the Sedgwick Museum, while the letters M.P.G. and T. respectively indicate the Jermyn Street Museum and the Torquay Museum. The index numbers following these letters refer to the individual specimens or tablets in the collections.

CRUSTACEA.

Genus HOMALONOTUS.

Homalonotus (*Digonus*) *goniopygæus* Woodward.

1882. *Homalonotus goniopygæus* Woodward, GEOL. MAG., p. 157, Pl IV, Fig. 1, ? 2.

1918. *Homalonotus (Digonus) goniopygæus* Reed, GEOL. MAG., pp. 317, 324.

The original specimen, consisting of a pygidium, which is in the Sedgwick Museum, was described by Dr. Woodward as follows: "The axis is very broad in proportion to the lateral portions, and the division between them is but slight. Breadth of axis at proximal border 6 lines. It is composed of from 12–13 annuli or coalesced caudal rings, the corrugations of which are slightly bent downwards on each side and continued to the border of the pygidium as well-developed side-ribs. The costæ diminish in size and strength from the proximal border, till they disappear near the hinder part of the axis about 4½ lines from the extremity, which is smooth or nearly so. There are no spines or other ornamentation on the surface of the specimen."

A few additional remarks may here be made on this pygidium. It has an elongated, triangular shape, but its lateral edges are hidden by matrix, and its tip is slightly broken. The convexity of the general surface is gentle at the proximal end, but increases somewhat towards the tip. The sides of the pygidium converge at first at an angle of about 45 degrees, but behind the pleuræ the rate of tapering of the pygidium is rather slower. There are only 11–12 distinct rings on the axis, the posterior fifth part of the axis having the narrow rings only faintly marked, and finally becoming obsolete. The axis is very greatly convex in front, and tapers rapidly, but becomes more convex and tapers more slowly towards its indistinct tip, which forms a blunt point circumscribed by a weak furrow, and

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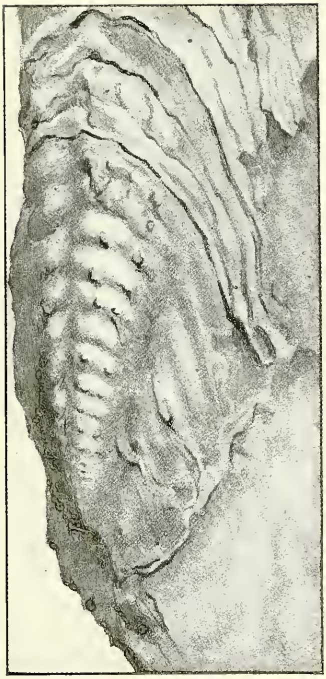
[1] Woodward, ibid., 1882, p. 157, Pl. IV, Figs. 1–3.

[2] Whidborne, ibid., 1901, pp. 533–40, Pl. XVIII.

[3] Jukes-Browne & Newton, ibid., 1914, pp. 311–18.



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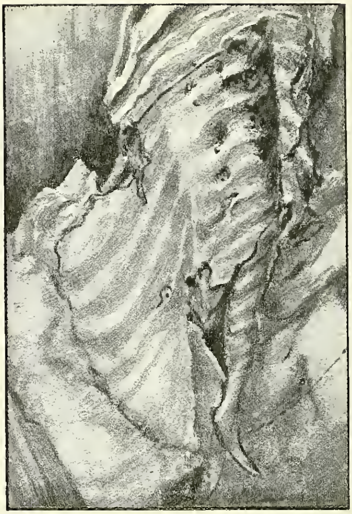

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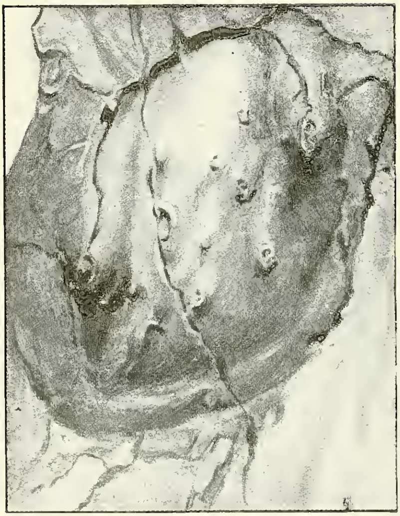

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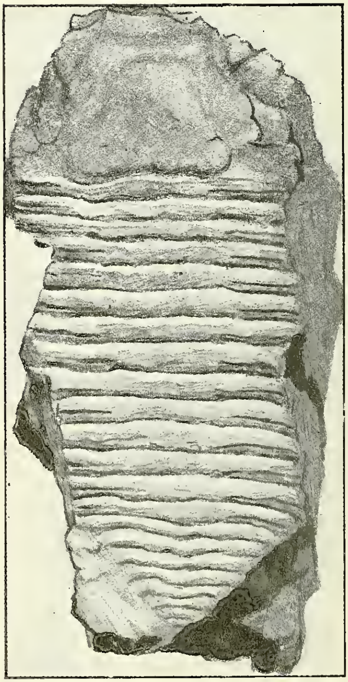

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NEW LOWER DEVONIAN HOMALONOTI.

does not reach the end of the pygidium. There are only eight pleuræ on the lateral lobes, and of these the first six plainly correspond with axial rings; but the narrow posterior part of the lateral lobes appears to be smooth and unfurrowed. The pleuræ are nearly straight, and are directed gently backwards at increasingly acute angles to the sides of the axis. The axial furrows are very weakly impressed. The general surface of the axis and pleuræ is covered with closely set small hollow tubercles.

Woodward believed that this pygidium resembled most nearly *H. Knighti* König, from the Ludlow, but the present author [1] has referred it to the subgenus *Digonus*, for its relations seem to be with *H. scabrosus* Koch [2] and *H. rhenanus* Koch,[3] but especially with *H. crassicauda* Sandb.,[4] as Kayser in his appendix to Koch's paper (op. cit., p. 152) has suggested. To this same group probably belongs *H. Vanuxemi* Hall,[5] of the North American Lower Devonian.

Dimensions.—"Length 12 lines; breadth at proximal border 11 lines" (Woodward, op. cit.).

Horizon.—Lower Devonian (Staddon Grits).

Locality.—Smugglers' Cove, Torquay (S. 87).

Homalonotus (*Burmeisterella*) *bifurcatus* sp.nov. (Pl. IV, Figs. 1–3.)

1918. *Homalonotus* (*Burmeisterella*) *bifurcatus* Reed, Geol. Mag., pp. 315, 325.

Definition.—Body elongated oval, gently convex from side to side. Head-shield broadly subtriangular, narrowing anteriorly to form a short truncate upturned snout (prora); genal angles rounded. Glabella subrhomboidal, widening slightly towards base, about one and a half times as long as wide, subtruncate anteriorly, completely circumscribed, bearing three longitudinal rows of tubercles (or spine-bases) of three tubercles in each row, and one outer pair of tubercles, the posterior tubercles being in all cases the largest, and the tubercles of the two lateral rows arranged in pairs; but the tubercles of the median row and of the outer pair alternate with the lateral ones and are smaller in size. Axial furrows shallow but distinct, converging to level of eyes, but anteriorly subparallel and uniting in front of glabella. Occipital ring broad, rounded, well defined by continuous occipital furrow arched forward rather suddenly in middle of base of glabella; pleuro-occipital portions with traces of small tubercle near axial furrows. Facial sutures having their posterior branches arched sharply outwards behind the eyes and cutting the lateral borders of the head-shield in front of the genal angles; anterior branches in front of eyes running

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[1] Reed, Geol. Mag., 1918, pp. 317, 324.

[2] Koch, Abh. k. preuss. geol. Landesanst., iv, 2, 1883, p. 43 [115], t. iii, figs. 8–10; t. iv.

[3] Ibid., p. 32 [104], t. iii, figs. 1–6.

[4] Ibid., p. 39 [111], t. v, figs. 1–5.

[5] Hall, Palæont. New York, vol. iii, 1859, p. 352, pl. lxxiii, figs. 9–13; Hall and Clarke, ibid., vol. vii, 1887, p. 11, pl. Vb; Clarke, Mem. 9, New York State Mus., pt. ii, 1909, p. 95, pl. xxii, figs. 2–6.

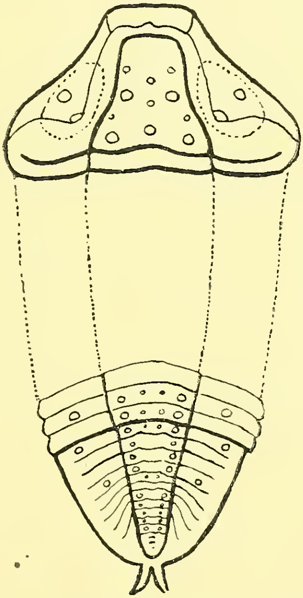
forwards at first with a slight convergence, but then rather suddenly bending inwards to traverse the pre-glabellar region and unite in a short median point, thus conjointly forming a distinct transverse suture, which defines the prora posteriorly. Epistomal (= rostral) sutures arising from the points at which the facial sutures bend inwards, and forming a pair of short subparallel sutures bounding the prora laterally, and cutting the anterior margin of the head-shield at right angles. Epistomal (= rostral) plate situated on lower surface of head-shield, subtriangular in shape, bearing a stout median apiculus, and bounded by the inferior continuation of the epistomal sutures, which cut it off from the flattened triangular lateral portions of the doublure. Cheeks with general surface convex and elevated. Free cheeks, with inner portion swollen and rising to maximum height at eyes, having large rounded boss or tubercle situated towards margin slightly in front of eyes; margin simple, without definite border. Eyes small, situated rather close to the glabella on elevated portion of cheeks at level of second lateral glabellar tubercles. Thorax of 13 segments, strongly convex. Axis broad, gently convex, faintly marked off from pleural portions. Axial rings bearing two pairs of tubercles, of which the outer ones are the larger. Pleuræ arched down on each side, gently flattened, particularly towards extremities, which are obtusely rounded and slightly curved forwards. Twelfth pleura bearing large rounded boss at half its length, but absent from eleventh and thirteenth pleuræ. [Anterior thoracic segments not sufficiently preserved for determination of characters.] Pygidium elongated, semi-elliptical in shape, with simple lateral margins, but furnished posteriorly with a short bifurcated spinose process. Axis long, conical, convex, slowly tapering, composed of eleven complete rings, with traces of one or two more very faintly indicated rings followed by a short non-annulated terminal portion with a blunt tip nearly touching base of posterior forked process. Axial rings well defined, some bearing tubercles, i.e. four tubercles on the first ring like those on the last axial ring of the thorax, two faint ones on the second ring, and two distinct ones on the third and fourth rings, apparently corresponding with the outer ones of the first ring; the fifth ring has two smaller ones, apparently corresponding with the inner pair; the sixth ring has none; the seventh ring has the two outer ones; the eighth to tenth rings have only faint traces of one outer pair; the eleventh has one more distinct pair. Axial furrows strong, distinct. Lateral lobes arched gently down on each side, with smooth undefined narrow border. Seven or eight distinct flattened pleuræ on each side, nearly straight, but with the ends slightly curved, not reaching margin, and with traces of a large low boss or tubercle on first pleuræ at about two-thirds its length and of a more distinct one on the fourth pleura at about half its length. Posterior end of pygidium furnished with a pair of closely placed, slightly diverging curved spines arising from a common base, horizontally extended, and about one-sixth the length of the pygidium. Surface of shell ornamented with small distant granules.

Dimensions.—(The specimen is laterally compressed and distorted.)

		mm.
Length of head-shield (actual)	about	40
Width of head-shield (actual)	,,	40
Length of glabella	,,	30
Width of glabella at base	,,	21
Length of pygidium (actual) to base of spines .	,,	33
Width of pygidium (actual)	,,	44
Width of axis of pygidium (actual) at front end	,,	15
Length of terminal spines	,,	6

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, above Meadfoot Bay, Torquay. Sedgwick Museum (S. 88) (S. 6).



Remarks.—The material on which this new species *H. bifurcatus* is founded consists of the laterally compressed and somewhat obliquely distorted cast and internal impression of a nearly complete individual (S. 88). All the parts of the body are in their natural position, except the head-shield, which has been bent back under the body and thus broken off from the thorax, but it is only slightly displaced from its proper position of attachment. The internal cast of the head-shield therefore points backwards in the specimen, and is attached to the impression of the thorax and pygidium. There is also the impression of part of the doublure and epistomal plate of the same head-shield, but the cast of these parts is not preserved.

The thorax is not well exhibited, being crushed and hidden by matrix, but the last three or four segments are sufficiently perfect to show the tubercles on the axis and the nodes on the pleuræ. The pygidium is nearly complete, though distorted; the right lateral lobe is almost uninjured; the axis exhibits its characters well in the cast and impression, and the bifurcated terminal spine shows distinctly on the left side of the impression, but the cast has the posterior end of the pygidium broken off.

There is also a portion of a large pygidium from the same locality in the Sedgwick Museum (S. 6), which is represented by the internal cast and the external impression, and may belong to the same species. This specimen has its axis, measuring over 30 mm. in width, at its front end, but only four rings are preserved. Of these the first and third rings bear two pairs of tubercles, of which the outer ones are the larger; the second ring only possesses one pair corresponding to the outer ones, and the fourth ring only the inner pair.

With regard to the relations of this species, we must first notice the close resemblance of the pygidium to that of *H. elongatus*, Salter,[1] from the Lower Devonian of Meadfoot, but the forked mucro at its extremity is peculiar, and recalls the species from the Rhine described by Koch[2] as *H. aculeatus*, though in his figure this special feature is not represented. It may be remarked that a similar peculiar bifurcated termination of the pygidium is present in some American species of *Dalmanites* (*Odontocephalus*) from the Devonian (e.g. *D. selenurus* Eaton[3] and *D. bifidus* Hall[4]). The head-shield and thorax of *H. Champernownei* Woodw.[5] appear to possess nearly the same characters as our new species, particularly in the tuberculation of the head-shield, but the anterior margin, prora, and course of the transverse suture are not known in the imperfectly preserved type-specimen which was figured by Woodward, and the pygidium appears to be different in its axial characters, and certainly lacks the posterior forked termination. The axial rings of the thorax are also stated to bear only one pair of tubercles instead of two pairs. The head-shields of *H. armatus* Burm.[6] and *H. subarmatus* Koch,[7] so far as they are known, seem allied to *H. bifurcatus*, especially in their tuberculation, but the pygidia are different.

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[1] Salter, Mon. Brit. Trilob., p. 122, pl. x, figs. 1–2.

[2] Koch, op. cit., p. 93, t. i, fig. 7.

[3] Hall, Palæont. New York, vol. vii, 1888, p. 49, pl. xiB, figs. 15–21.

[4] Ibid., p. 53, pl. xiB, figs. 22–5.

[5] Woodward, Geol. Mag., 1881, p. 489, Pl. XIII.

[6] Koch, op. cit., p. 84, t. i, figs. 1–4, and p. 151.

[7] Frech, Leth. Palæoz., Bd. ii, 1897–1902, p. 218, text-figure.

(*To be continued.*)

Hornblendite at Vavasour Mine, Cantley, Quebec.

By J. Stansfield.

(By permission of the Directing Geologist, Geological Survey of Canada.)

THE interesting rock-type hornblendite occurs at the Vavasour Mine, though it has only a very small development. It covers an area of about 600 square feet and is cut by two of the apatite-mica veins, which are so numerous at this locality. The rock was incorrectly marked amphibolite on the map in Guide Book 3, International Geological Congress, xii, 1913, facing p. 112.

In the hand specimen it is coarsely crystalline and shiny black by reason of the excellent cleavage of the hornblende. The only minerals seen in the hand-specimen in addition to hornblende are pyrite and an occasional speck or veinlet of a greenish mineral. Under the microscope, in addition to the green or greenish-brown hornblende there is seen a small amount of a scapolite of low birefringence, a phlogopite mica, a little sphene, and a grain or two of black iron-ore. Augite within one of the crystals of hornblende appears to indicate the relation of the rock to the gabbro of the remainder of the hill, and the probable close genetic connexion of the hornblende with augite.

The chemical composition of the rock is given below:—

SiO_2	42·21
Al_2O_3	16·32
Fe_2O_3	3·79
FeO	7·49
CaO	11·01
MgO	12·00
Na_2O	3·67
K_2O	2·67
CO_2	·72
H_2O	·45
S	·22
	100·55

On an Exposure of Sands and Gravels containing Marine Shells at Easington, Co. Durham.

By David Woolacott, D.Sc., F.G.S.

THE purposes of this short paper are to place on record and to bring to the notice of geologists a deposit of sands and gravels containing numerous marine shells which is exposed on the Durham coast north of Easington. Marine shells (*Littorina*, *Cyprina*, etc.) have been collected before from sands and gravels lying above sea-level on this coast,[1] but the deposits containing them have usually

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[1] Shells were collected at Marsden by Howse and others at 100–50 feet, and also at Cleadon at 100 feet. I have collected shell fragments of *Littorina*, *Cyprina*, and *Cardium* and one whole specimen of *Littorina* from the Cleadon Sand Pit at 100 feet, and numerous entire specimens of *Littorina littorea* and fragments of *Cyprina* from sands and gravels in Fulwell Quarries

been removed in the course of quarrying operations, and no collection of shells has been preserved in any museum; it is therefore of interest that a deposit has lately been observed which can be examined at any time by geologists, and from which specimens of shells can easily be obtained. It is also of importance that the exact mode of origin of these particular deposits should be determined.

The exposure here noticed occurs in the cliff on the south-east flank of Beacon Hill, about half a mile north of Easington station, which is on the N.E.R. coast line midway between Sunderland and Hartlepool. It can be examined in a steep footpath (the top of which is marked by a stile) leading down to the shore at this point. The deposit occurs at an elevation of about 60 feet, and consists of horizontally and regularly bedded sands and gravels which rest on a level shelf of Magnesian Limestone, and which are distinctly traceable for a considerable distance to the north and south. The gravels can be seen in the railway cutting behind for at least 30 feet above the level of the shelf. The pebbles consist mainly of water-worn fragments of Magnesian Limestone, but others of quartz, sandstone, quartzite, rhyolite (Lake District), and Cheviot porphyrite occur. It is, therefore, late Glacial or post-Glacial in origin.

Many of the pebbles are bored by annelids (*Polydora*) and others by *Saxicava*. In the case of the latter some of the shells are still in their holes. The sands and gravels are full of large and small, whole and broken shells, some of which are in an excellent state of preservation. The species include *Littorina littorea*, *L. obtusata*, *Patella vulgaris*, *Purpura lapillus*, *Mytilus edulis*, *Cyprina islandica*, *Saxicava*, *Pecten*. Several foraminifera have been proved to occur in the sand. In one part of the deposit some *Helix* are cemented in, and Dr. Trechmann informs me that in the conglomerate a little further south many rodents' bones occur.

This deposit is of special interest as it is undoubtedly of the same origin as other sands and gravels which occur 12 miles to the north in Durham (their connexion can, indeed, be traced), and which can be proved up to 150 feet above sea-level. Howse described some caves at Marsden at this height in 1879, which he said were sea-caves, and associated the sands and gravels on these hills with their formation,[1] Kirkby noticed sands and gravels at Fulwell resting

at 150 feet. Trechmann has collected broken fragments of *Mactra*, *Turritella*, and *Cyprina islandica* from the Sheraton Kaims, which are about 4 miles inland at an elevation of 400 feet, and I have collected shell-fragments from the spreads of sand and gravel at Salton Piercy, near Hartlepool. It is, however, important to disconnect clearly the shell-bearing deposits which are found lying along the Durham coast up to 150 feet from the shell-bearing gravels and sands of the Kaims, and the spreads of sand and gravel which are associated with them.

[1] "Old Sea-caves and Sea-beach at Whitburn": Nat. Hist. Trans. Northumberland, Durham, and Newcastle, vol. vii, 1880, p. 361.

on rock against a terrace, which he describes as water-worn,[1] and Lebour states that the deposits on Cleadon Hills is a typical example of a raised beach.[2] I have described both the deposits at Cleadon and Fulwell, and from the evidence obtained regarded them as raised beaches.[3] At the latter place the sands and gravels were banked up against a buried terrace and contained at one point a large number of whole specimens of *Littorina littorea*. (The buried rock-terrace appeared to be water-worn and to have been cut by the agent that deposited the gravels.) The sands and gravels at Marsden are mapped as raised beaches on the Geological Survey maps of the district.[4] Lamplugh, Wright, and some Yorkshire geologists have doubted that these deposits are of direct marine origin, chiefly because no raised beaches occur in Yorkshire, and Dr. Trechmann states he is unable to see the necessity of assuming these gravel-deposits to be of marine origin.[5] The shells collected from these deposits have been referred to as having been obtained from kitchen middens.[6] At Kelsea Hill, near Hull, gravels and sands containing numerous marine shells (some of which are similar to those occurring on the Durham coast) can be proved to have been transported inland for some miles by ice from the bed of the North Sea. Since collecting in the Easington deposit I have re-examined the Kelsea Hill deposit, and have been struck by the similarity of the fauna and the mode of preservation of the shells and by the occurrence in both deposits of bored rocks with *Saxicava* in place, etc.; but have been impressed by the dissimilarity in their mode of occurrence.

The horizontally and regularly bedded gravels at Easington seem to have been deposited on the platform on which they lie, and this level shelf would appear to have been cut by wave action when the deposit was formed. This formation has, indeed, all the characters of a true raised beach, but it is possible that these may be deceptive. After my re-examination of the Kelsea Hill deposit I admit this possibility. I am, however, not convinced that the evidence obtained from an examination of the deposit is sufficient to prove that it is not an uplifted sea-beach.

If it is not of direct marine origin two other methods of formation are possible. It may be material carried by ice from the bed of the North Sea and deposited above sea-level. (There would appear

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[1] *Geologist*, 1860, p. 294.

[2] *Geology of Northumberland and Durham*, p. 19.

[3] Nat. Hist. Trans. Northumberland, etc., 1900, and Univ. Durham Phil. Soc. Trans., 1907; Quart. Journ. Geol. Soc., vol. lxi, 1905, and *Geog. Journ.*, July, 1907.

[4] *Geog. Journ.*, July, 1907, p. 56.

[5] Quart. Journ. Geol. Soc., vol. lxxi, pt. i, 1915, p. 75.

[6] It is peculiar that a kitchen midden occurs on Fulwell Hills about 20 feet above the highest point at which these gravels occur. The suggestion that the shells in these deposits were from a kitchen midden is shown, by the nature of the deposit at Easington and also by the fragments that can be got from almost any exposure, to have been nonsense.

to be two ways in which this could have been done. It could either have been pushed inland by the ice and deposited at a higher level,[1] or there is the possibility of it being lifted up from the bed of the sea and carried forward as suggested by Debenham.[2]) Its regularly bedded and undisturbed nature and its extent are entirely against the idea that it has been carried by ice and dumped down in the place in which it occurs. On the other hand, the evidence is certainly in favour of it having been deposited in place by water; indeed, it would appear to have been formed as a marginal deposit. The other possible mode of formation is, therefore, that it was formed on the edge of a glacier-lake held up by ice lying off the Durham coast near the end of the Glacial Period, and that it thus consists of glacial material carried inland and afterwards re-assorted by water on the margin of an ice-dammed lake. The unbroken nature of the shells and their variety are strongly against this view.[3] No transported glacial material from the bed of the North Sea with such a varied fauna is known to exist in Durham.[4] From the Sheraton Kaims, which occur a few miles to the south and are about 4 miles inland at an elevation of 400 feet, Dr. Trechmann, after careful searching, has only been able to collect some very broken fragments of *Cyprina islandica*, *Mactra*, and *Turritella*[5]; yet in this deposit whole well-preserved shells of *Littorina*, *Patella*, *Saxicava*, and *Purpura* occur.

This deposit and the associated sands and gravels on the Durham coast are therefore of special interest. If they are raised beaches they obviously raise a peculiar question regarding the nature of the uplift that produced them, and if they are not they show how deceptive the evidence obtained from the mode of occurrence of deposits may often be, and they suggest a query regarding the extent of the glacier-lake of which they are the marginal deposits. All geologists to whom I have shown the sands and gravels at Easington, including some who doubted the existence of raised beaches on the Durham coast, regard them as being of direct margin origin, or admit that the deposit is masquerading as an uplifted marginal marine formation. Certainly geologists who described these superficial deposits on the Durham coast as raised beaches would appear to have been justified. Now that a fairly complete record of the glacial deposits of this coast has been worked out it appears of importance that the mode of origin of these particular formations should be determined. They can be much more clearly examined at

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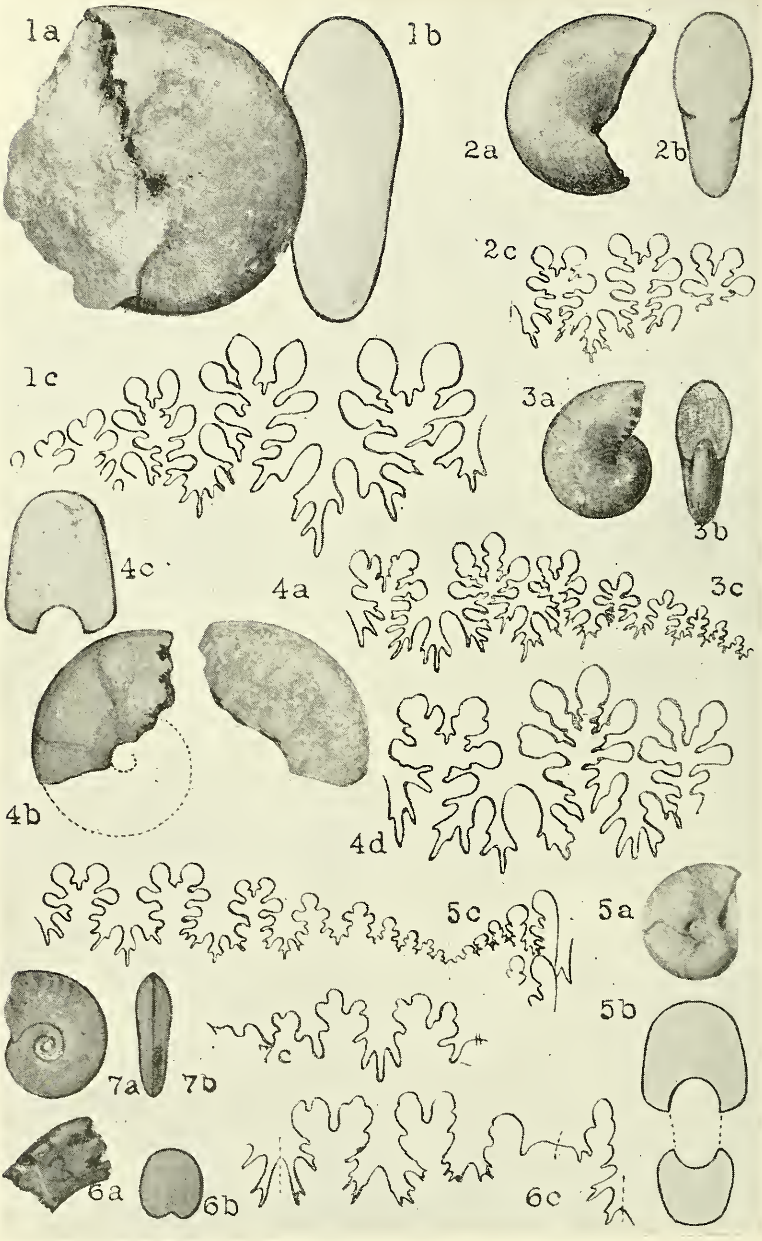
[1] Deposits have been observed raised from the sea bed in Spitsbergen by Garwood, Gregory, and Lamplugh.

[2] Quart. Journ. Geol. Soc., vol. lxxv, 1920.

[3] It is admitted that shell-bearing gravels have been transported inland in County Durham. The question at issue is whether there has been an uplift of the coastal area of Durham since Glacial times.

[4] I have not seen any *Patella* in place on the rock shelf, although some appeared to have been attached to the large pebbles in the gravel.

[5] Quart. Journ. Geol. Soc., vol. lxxi, 1915, p. 74.



J. W. G. phot., L. F. S. del.

Jurassic Ammonites from East Africa.

To face p. 311.]

Easington than at any other point, and a thorough examination of this deposit should finally settle the question as to whether raised beaches do occur on the coast of north-east England. I should be glad to give any further particulars to any geologists who may desire to examine this deposit, and if it can be arranged should be pleased to accompany them to the exposure. Any expression of opinion regarding the mode of origin of this deposit after it has been examined would be welcomed. I have placed a collection of shells from it in the Sunderland Museum, and have also given some specimens to the Curator of the Hancock Museum, Newcastle.

On Jurassic Ammonites from East Africa, collected by Prof. J. W. Gregory

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

(PLATE V.)

THE small but very interesting collection of Ammonites described in the following pages was obtained during the summer of 1919 by Professor J. W. Gregory, to whom the writer is indebted for permission to study them. There are seven specimens altogether, three of them fragmentary, and all probably originally pyritized, but now converted into limonite. Though immature or fragmentary, all the specimens were seen to have indications of suture-lines, so that their study promised definite results even if, at first sight, it was difficult to place the fauna in the geological sequence. Superficially, there was greater resemblance to the Lower Cretaceous fauna (with *Phylloceras* of the *heterophyllum* group and *Lytoceras quadrisulcatum*) described from East Africa by Krenkel[1] than to the Sequanian fauna of Mombasa, recorded by Dacqué,[2] and a large series of which is preserved in the British Museum (Nat. Hist.).

On closer investigation, however, and after preparation of the suture-lines, it became evident that the age of the Ammonites corresponded with the presumed stratigraphical position of the beds which yielded them, namely "Bathonian, or post-Bathonian, but pre-Sequanian". Professor Gregory adds (in litt.) that the Ammonite beds [limestones and shales] are separated from the fossiliferous Sequanian by a considerable thickness of strata. The corals of the limestone immediately underlying the Ammonite-bearing beds, according to Professor Gregory, are not of the same genera as the known Bathonian corals of East Africa. Also they are not the same species as those of the Bathonian of Kutch, and Professor Gregory was at first disposed to put them as post-Bathonian. On the other

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[1] "Die Untere Kreide von Deutsch-Ostafrika": Beitr. Pal. Geol. Ost.-Ung., vol. xxiii, pt. iv, 1910, pp. 201–50, 4 plates.

[2] "Dogger und Malm aus Ostafrika": ib., vol. xxiii, pt. i, 1910, pp. 1–63, 6 plates.

hand, Mr. R. B. Newton compared one of the molluscs to a species from the Bathonian of Abyssinia.

It was, therefore, of interest to obtain, if possible, more exact information from a study of the Ammonites, however few and fragmentary these were, and the writer is of opinion that the evidence points to a probable Bathonian[1] age of the Ammonite fauna.

DESCRIPTION OF AMMONITES

Genus PHYLLOCERAS, Suess.

Phylloceras aff. *Kudernatschi* Hauer, sp. (Pl. V, Figs. 1*a*–*c*.)

1852. *A. heterophyllus* (Sowerby), var., Kudernatsch, "Amm. Swinitza": Abh. k.k. R. A. Vienna, vol. i, pt. ii, p. 6, pl. i, figs. 5–9.
1854. *A. Kudernatschi* Hauer, "Beitr. Kenntn. Heterophyll. Öst. Mon.": Sitz.-Ber. Akad. Wiss., vol. xii, pt. iv, p. 902.
1860. *A. Kudernatschi* (Hauer), Ooster, Cat. Ceph. Foss., pt. iv, p. 72, pl. xvii, figs. 9–11.
1871. *Phylloceras Kudernatschi* (Hauer), Neumayr, Jurastud. (3), "Phyllocer. Dogger & Malm": Jb. k.k. R.A., vol. xxi, Hft. iii, p. 310, pl. xii, figs. 4–5.
1877. ,, ,, (Hauer), Gemmellaro, "Sopra alcuni Fossili della zona con *Posidonomya alpina*, Gras. di Sicilia": Faune Giur. & Lias., p. 128, pl. xviii, figs. 3 4.
1890. ,, ,, (Hauer), Jüssen, "Beitr. Kentn. Klaus-Schicht. N. Alp": Jb. k.k. R.A., vol. xl, p. 387, pl. ii, fig. 1.
1892. ,, ,, (Hauer), Neumayr & Uhlig, "Üb. v. Abich i. Kaukasus gesamm. Jura-Fossil.": Denkschr. Akad. Wiss. M. Naturw. Cl., vol. lix, p. 33.
1897. ,, ,, (Hauer), Hochstetter, "Die Klippe v. St. Veit b. Wien": Jb. k.k. R.A., vol. xlvii, pt. i, p. 141.
1905. ,, ,, (Hauer), Popovici-Hatzeg, "Les Céph. Jurass. Mt. Strunga": Mém. Soc. Géol. France, vol. xiii, fasc. 3, p. 10, pl. i, figs. 1–4.

Dimensions.—	
Diameter . . .	39 mm.
Height of the last whorl . . .	60 per cent of the diameter.
Thickness . . .	38 ,, ,, ,,
Umbilicus . . .	5 ,, ,, ,,

Description.—This ammonite is a typical *Phylloceras*, with almost closed umbilicus and an elliptical section with evenly rounded sides. The specimen is not perfect, however, the shell not being continued into the mass of limonite shown in Fig. 1*a*. Also, since the specimen is septate throughout, it only represents the inner whorls of a larger ammonite. The test is somewhat imperfectly preserved, and shows fine, radial striation at the anterior portion, but near the end of the shell the ornament is greatly worn. Even here, however, the fine

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[1] The zone of *Macrocephalites macrocephalus* (Cornbrash) should be included in the Bathonian, and the Callovian considered to begin with the zone of *Proplanulites Koenigi*. This is contrary to Continental usage; but the (English) type successions should be adhered to.

spiral lines along the periphery, forming a peculiar feature of the test in this specimen, still persist. The extremely fine radial lines describe a strong forward curve on the inner third of the lateral area, bend back again towards the outer third, and near the periphery once more swing gently forward, after the style of the ornament in Popovici-Hatzeg's good photographs. Though the ornament is worn, some of the costæ are more prominent than others, and it seems probable that the ornament was that typical of *Phylloceras Kudernatschi*. It also appears that the test consisted of four layers, as in *Phylloceras. Malayanum* G. Böhm, described by both the author of that species[1] and by Dacqué,[2] namely a smooth inner layer, a weakly costate second layer, followed by the lineate third layer with its peculiar string- or tube-like costæ, easily detached and preserved (in the specimen under examination) only in one or two places. The fourth (smooth) outer layer of the test is absent. The ventral area is slightly compressed as in the section given by Jüssen,[3] yet regularly rounded; and the greatest thickness of the whorl is about midway between the periphery and the umbilicus. The latter is very narrow, funnel-like, and very deep, with the sides regularly rounding into it.

The suture-line could not be exposed plainly enough for complete delineation, but apart from the six saddles shown in Fig. 1*c* (drawn at a diameter of about 30 mm.) there are probably two or three more monophyllic saddles on the umbilical slope. The external saddle is very distinctly diphyllic, the first lateral saddle tetraphyllic, and the following three saddles diphyllic again.

Observations.—The small umbilicus and linear ornament of this specimen, together with the absence of constrictions, characterize it as a member of the *heterophyllum* group of the genus *Phylloceras*, which group ranges from the Lower Lias up into the Cretaceous. Its general shape and suture-line seem to agree very well with *Phylloceras Kudernatschi* (Hauer). According to Neumayr, Gemmellaro, and Jüssen, the umbilicus of that species amounts to 7 per cent of the diameter, whereas the figures given by Popovici-Hatzeg show a smaller umbilicus, comparable with that of the present specimen. There also is some variation in the whorl-shape. Kudernatsch's type (pl. i, figs. 5 and 6) shows the greatest thickness near the middle of the whorl, whereas his smaller specimen (figs. 8 and 9) and the ammonite figured by Neumayr have the region of greatest thickness nearer the umbilicus. On the other hand, the excellent photographs given by Popovici-Hatzeg show a laterally flattened whorl. Apart from the slightly larger umbilicus of Jüssen's figure (not in agreement with that of Fig. 1*a*, and therefore probably drawn too open) the section given by that author best

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[1] "Beitr. Geol. Nied. Ind.": *Palæontographica*, Supp., vol. iv, pt. i, 3. "Oxford v. Wai Galo," 1907, pl. xiv, figs. 4*b*, 5.

[2] Op. cit., 1910, pp. 6, 7, pl. i, figs. 1–3.

[3] Op. cit., 1890, pl. ii, fig. 1*b*.

agrees with the whorl-outline of the specimen here described. In Neumayr's figure of *Phylloceras Kudernatschi* the ventral area is truncated; but this flattening is shown neither in the type nor in the other illustrations cited, though Dr. Till [1] apparently lays stress on it.

The suture-line of the type is slightly more complicated than the one here reproduced (Fig. 1*c*), as is also that given by Neumayr, and especially the saddles are slenderer. This difference, however, is accounted for by the different size of the specimens. Neumayr's figure, on the other hand, shows exactly the same endings of the saddles as far as the third auxiliary.

The bundling of the striæ seems to become more pronounced in the larger specimens only, but the fact that the ornament is worn in the specimen under consideration gives it a certain resemblance to *Phylloceras modestum* Tornquist [2] from the *Sonninia* beds of the Espinazito Pass. This form, however, is thinner, and has a larger umbilicus (9 per cent).

Horizon and Distribution.—Neumayr and Uhlig [3] stated that (down till 1892) *Phylloceras Kudernatschi* was known only from the Mediterranean Klaus beds = Lower Bathonian = zone of *Parkinsonia ferruginea*. But in some of the beds referred to this horizon, e.g. the hæmatite beds of Swinitza or the *Posidonomya alpina* beds of the Italian Alps, the *fusca* and even the *aspidoides* zones of the Bathonian seem to be represented in addition to the lower zone. Haug [4] records *Ph. Kudernatschi* from the Bajocian (zone of *Cosmoceras subfurcatum* = *niortensis* up to *zigzag* hemeræ probably) of the Basses-Alpes. The species has also been found in the Glarner Alps of Switzerland, near Hallstatt, Gosau, Vienna, etc., in Austria, in the Carpathians, in Sicily, and in the Caucasus.

Locality.—No. 19. From beside the coral limestone on the Mombasa pipe-line at mile $\frac{12}{5}$. (Single specimen.)

Phylloceras sp. indet. (Pl. V, Figs. 2*a*–*c*.)

Dimensions.—	Diameter . .	25 mm.
	Height of the last whorl . .	58 per cent of the diameter.
	Thickness . .	42 ,, ,, ,,
	Umbilicus . .	4 ,, ,, ,,

Description.—This specimen consists of a little over half a whorl (wholly septate); and it has been rolled, so that though fragments of the test remain there is no trace of the ornament. The ammonite is very similar in shape to the specimen above referred to *Phylloceras Kudernatschi*, but a little thicker (42 per cent instead of 38 per cent),

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[1] "Amm. Fauna d. Kelloway v. Villány": Beitr. Pal. Geol. Öst.-Ung., vol. xxiv, pt. ii, 1911, p. 255.

[2] "D. Dogger a. Espinazito Pass": Pal. Abh. Dames, N.F., vol. iv, pt. ii, 1898, p. 29, pl. v (xviii), fig. 2.

[3] Op. cit., p. 33.

[4] "Les Chaines Subalpines, etc.": Bull. Service Carte Géol. France, iii, No. 21, 1891, p. 74.

and the periphery thus appears more rounded. The umbilicus is very small and deep, and the sides are regularly rounded into it.

The suture-line could only partly be drawn, and this portion is composite, taken from both the anterior and posterior ends of the specimen. Apart from the diphyllic external and two lateral saddles shown in Fig. 2*c*, there are three more diphyllic saddles; but the remainder of the suture-line, apparently consisting of three more saddles, cannot be clearly made out. The suture-line, then, differs from that of the above specimen chiefly in having a more complex and deeper external lobe and a more diphyllic first lateral saddle.

Observations.—There is great resemblance in the suture-line and appearance (of the smooth inner whorls) to the Callovian *Phylloceras subobtusiforme* Pompeckj[1] from Alaska. But this form is a little thicker, and apparently has an umbilical edge, since it is compared with *Phylloceras subobtusum* Kudernatsch and *Phylloceras Abichi* Uhlig. The fact that the ornament is not preserved prevents closer comparison with *Ph. isomorphum* Gemmellaro,[2] which has similar (but variable) dimensions. Also the suture-line of this form has slenderer saddles and folioles. Since, however, the suture-line of the earlier portion of the East African specimen shows, in this respect, greater resemblance to Gemmellaro's figure than the last suture-lines (a matter of preservation), this point is less significant than the larger umbilicus in the Sicilian species.

Phylloceras trifoliatum Neumayr,[3] from the Bajocian of the Carpathians, also comes close to the present form, but its suture-line is characterized by a triphyllic first lateral saddle. Vacek[4] stated that the specimen from San Vigilio (from which the suture-line given by Neumayr in Fig. 2 was taken) was not identical with the Hungarian *Ph. trifoliatum* and belonged to *Ph. chonomphalum* Vacek of a different group. This point seems to have escaped Prinz,[5] whose otherwise unconvincing divisions within the genus *Phylloceras* have not been adopted by the writer.[6] Of the Bajocian forms of *Phylloceras* described by Prinz, *Ph. baconicum*[7] is very near the present specimen, but its suture-line is more complex than the one here figured (though taken from a larger specimen).

The absence of constrictions and its general appearance

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[1] "Jurafossil. aus Alaska": Verh. Russ. Kais. Mineral. Ges. St. Petersb., ser. II, vol. xxxviii, 1900, p. 247, pl. vii, fig. 1.

[2] *Faune Giur. & Lias.*, pt. i, 1872, p. 6, pl. i, fig. 1; pt. v, 1877, p. 130, pl. xix, fig. 16.

[3] "Jurastudien," ii: loc. cit., p. 309, pl. xii, figs. 2, 3.

[4] "Üb. Fauna Ool. Cap San Vigilio": Abh. k.k. R.A., Vienna, vol. xii, 1886, p. 69.

[5] "Die Fauna ält. Jurabild. N.O. Bakony": Mitt. Jahrb. Ungar. Geol. Anst., vol. xv, 1904, p. 40.

[6] Jullien's (C. R. somm. Soc. Géol. France, June 19, 1911) divisions and speculations on sexual dimorphism among *Phylloceras* also seem unfounded.

[7] Ib., p. 38, pl. xxvii, fig. 2.

characterize the specimen as a member of the group of *Ph. heterophyllum*, and it is probable that it belongs to the same lineage as, and is a near relative of, *Phylloceras Kudernatschi* Hauer.

Locality.—This specimen (No. 551) was found (isolated) to the west of the Mwachi River, about $\frac{17}{0}$.

Phylloceras cf. *Kunthi* Neumayr. (Pl. V, Fig. 3*a–c*.)

1871. *Phylloceras Kunthi* Neumayr, "Jurastudien," ii: loc. cit., p. 312, pl. xii, fig. 6; pl. xiii, fig. 1.
1905. *Ph.* n.sp. ind., Popovici-Hatzeg, "Les Céph. Jurass. Moy. Mt. Strunga": loc. cit., p. 11, pl. iv, fig. 8.
1910. *Ph.* cf. *Kunthi* (Neumayr), Till, "Amm. Fauna d. Kelloway v. Villány": loc. cit., p. 253.

Dimensions.—Diameter	19	mm.
Height of the last whorl	59	per cent of the diameter.
Thickness	36	,, ,, ,,
Umbilicus	5	,, ,, ,,

Description.—This specimen is a wholly septate cast and has only a small portion of the test preserved, namely, on the periphery, near the beginning of the outer whorl. Here the ornament consists of distinct radial striæ (about eleven to the 2 mm. of test shown) after the manner of *Phylloceras Velledæ* Michelin sp. It is a little thinner than the two forms previously described; in its elongate elliptical section it more resembles that referred to *Ph. Kudernatschi*. The whorls show their greatest thickness about midway between the periphery and the umbilicus; the latter is narrow and deep.

The suture-lines are well exposed throughout the last whorl. Apart from the eight saddles shown in Fig. 3*c* there are three more saddles externally, and about seven saddles internally, making altogether about seventy elements. The external saddle shows branching of its terminal leaflets (after the manner of *Ph. serum* Oppel sp. and *Ph. semisulcatum* d'Orbigny sp.), and the first lateral saddle becomes triphyllic owing to the leaning over of its originally tetraphyllic summit to the ventral side. The three saddles following this are diphyllic, the next six monophyllic.

Observations.—The absence of constrictions and other points characterize this specimen as a form of the group of *Ph. heterophyllum*. Though in dimensions and whorl-shape it resembles the ammonite above referred to *Ph. Kudernatschi*, its complex suture-line distinguishes it at once from that species. The subdivision of the terminal leaflets of the external saddle, however, is indicated in Neumayr's figure of the suture-line of *Ph. Kudernatschi*,[1] though this subdivision is more reminiscent of *Ph. subobtusum* Kudernatsch and many forms of the group of *Ph. tatricum* Pusch.

The slender whorl-section of this specimen is not unlike that of

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[1] Loc. cit., pl. xii, fig. 4*c*.

Ph. Kunthi Neumayr, but is more rounded, and therefore nearer to the form described as *Phylloceras* n.sp. ind. by Popovici-Hatzeg, and compared with *Ph. Kunthi.* The thickness of the adult *Ph. Kunthi* is only 28 per cent of the diameter, but the inner whorl of the type-figure at a diameter still more than three times that of the specimen here described shows this thickness already increased to 32 per cent. The suture-line of *Ph. Kunthi*, according to Neumayr, is distinguished from that of *Ph. Kudernatschi* by a tetraphyllic first lateral saddle and a larger number of lobes. Dr. Till[1] also states that the suture-line of the flatter "Callovian" *Ph. Kunthi* is distinguished from that of the thicker Bathonian *Ph. Kudernatschi* by more numerous and more indented elements. In the small specimen under examination the first lateral saddle does not, of course, attain the great complexity of that of Neumayr's figure. The flatness of the periphery on which Till insists is not shown on the inner whorls, and, probably like that in Neumayr's figure of *Ph. Kudernatschi*, is accidental. The present specimen, however, is not definitely identified with *Ph. Kunthi* on account of its immaturity.

The very compressed *Ph. perplanum* Prinz[2] seems to belong to the same group of forms, but apparently in all the Bajocian species of the *heterophyllum* group the suture-line has undivided terminal leaflets to the saddles. On the other hand, there is a likeness to the suture-line of *Ph. subobtusum* Kudernatsch,[3] though whorl-shape, ornament, and umbilical rim are very distinct in that species. The specimens figured as *Ph. subobtusum* by Popovici-Hatzeg,[4] however, agree much better with the East African specimen. Only the umbilicus is larger; and Popovici-Hatzeg also states that up to a diameter of 25 mm. the shell is perfectly smooth.

Till[5] also describes a *Ph.* aff. *plicatum* Neumayr from the Callovian of Villány. Neumayr's figure[6] (at a diameter of 58 mm.) shows a whorl thickness of 36 per cent, which agrees very well with that stated above for Professor Gregory's specimen. The absence of the test on the latter, however, prevents closer comparison; besides, *Ph. plicatum* is Argovian, though apart from Hungary it has also been recorded from the Callovian of the Maritime Alps and of the Swiss Jura.

Of later forms, *Ph. isotypum* Benecke,[7] a species of the *acanthicus* zone (but recorded from the *bimammatum* zone by Pompeckj[8]),

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[1] Loc. cit., p. 252.

[2] Loc. cit., p. 38, pl. xxvii, figs. 3, 4.

[3] Loc. cit., 1852, pl. ii, figs. 1–3.

[4] Loc. cit., 1905, pl. ix, fig. 9 especially.

[5] Loc. cit., 1910, p. 254.

[6] Loc. cit., 1871, pl. xii, fig. 7 (inner whorl).

[7] Üb. Trias u. Jura i. d. Südalpen": Geogn. Pal. Beitr., 1865, p. 184, pl. vii, figs. 1, 2.

[8] *Beitr. Revision Amm. Schwäb. Jura*, 1893, pt. i, p. 29.

is very near to the present specimen both in whorl-shape and suture-line. The latter also greatly resembles *Ph. Riazi* de Loriol [1] from the *Renggeri* marls. The very complicated suture-line of the latter, however (at equally small dimensions), is distinguished by a lesser number of elements.

Horizon and Distribution.—*Phylloceras Kunthi* is widely distributed in the Callovian of the Mediterranean region (Austrian Alps, Hungary, Sicily, Daghestan, and India). The type comes from the zone of *Macrocephalites macrocephalus*. Haug [2] records this species with *Ph. disputabile*, *Protetragonites tripartitum*, and other Bathonian fossils from Chaudon, Basses-Alpes, whereas the ammonites doubtfully referred to it by Waagen [3] and Neumayr et Uhlig [4] came from the *athleta* beds.

Locality.—No. 550/I, Mwachi River, Pipe-line Crossing. Found together with *Protetragonites* cf. *tripartitum* Raspail sp. and *Hecticoceras* sp. juv.

Phylloceras cf. *disputabile* Zittel. (Pl. V, Figs. 4*a*–*d*.)

1893. *Phylloceras disputabile* (Zittel) Pompeckj, loc. cit.: Revision, p. 32. See there for synonymy.
1905. „ „ (Zittel) Popovici-Hatzeg, loc. cit., p. 13, pl. ii, figs. 1–9, text-fig. 3 on p. 13, figs. 4 and 5 on p. 14.

Dimensions.—Diameter	? 28 mm.
Height of the last whorl	? 55 per cent of the diameter.
Thickness	? 30 „ „ „
Umbilicus	? 14 „ „ „

Description.—This specimen consists of a whorl-fragment, about 27 mm. long, and the above measurements are based on the restoration of the complete shell given in Fig. 4*b*. The fragment is worn, and there is no trace of the shell-ornament left. The rounded umbilical edge is apparently preserved near the smaller end, and the sectional view, given in Fig. 4*c* (magnified two diameters), is drawn from this portion. Fig. 4*a* shows the (morphologically) left side of the specimen, which is poorly preserved, and does not show the constrictions. On the opposite side, represented in Fig. 4*b*, the two constrictions are present, but they become indistinct on the lateral area. The constrictions pass across the periphery with a slight forward bend, but the forward convexity at the side and the umbilical curve, indicated in the figure, are hardly distinct enough to warrant a definite description of their course. The sides of the

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[1] "Étude sur les Moll et brach. de l'Oxf. Inf. d. Jura Bern.": Mém. Soc. Pal. Suisse, vol. xxv, 1898, p. 110, pl. viii, figs. 8–12 and text-fig. 29 on p. 111.

[2] *Traité de Géologie*, vol. ii, fasc. 2, 1908, p. 1023.

[3] "Jurassic Fauna of Kutch": Pal. Indica, ser. ix, vol. i, 1873, p. 25, pl. v, fig. 2.

[4] Loc. cit., 1892, p. 33.

fragment are flattened, but gradually rounded off to the periphery, and very abruptly to the umbilicus; the greatest thickness of the whorl is at the umbilical edge. The small inclusion shown by the impression of the inner whorl indicates a fairly large umbilicus.

The suture-line is characterized by the slightly subdivided terminal folioles of the external saddle, and by an irregularly trifid first lateral saddle. The lateral elements are highly complicated, and both the saddles and their folioles are very slender.

Observations.—The slightly falcoid constrictions and complex suture-line characterize the specimen as belonging to the group of *Phylloceras Capitanei* (Catullo) Neumayr. There is great resemblance to the forms figured by Popovici-Hatzeg as *Ph. disputabile* Zittel, especially his smaller specimens; and the section given by that author (fig. 3 on p. 13) agrees very well at a similar diameter. On the other hand, the suture-line of the East African specimen is more complex and of the type of that of *Ph. Puschi* Oppel,[1] which according to Till [2] is often confused with *Ph. disputabile.* In d'Orbigny's specimen and in the examples referred to *Ph. Puschi* by Till, however, the umbilicus is only 6–7 per cent of the diameter. Petitclerc [3] united *Ph. Puschi* with *Ph. Lajouxense* de Loriol,[4] and the young of the latter species would agree with the specimen under consideration in the large umbilicus; but the suture-line is too simple in *Ph. Lajouxense*, the whorl section too inflated, and the constrictions (apparently) too straight.

The specimen of *Ph. disputabile* figured by Dacqué [5] from the Dogger of Pendambili (railway line from Dar-es-Salaam to Morogoro) differs from the present example both in suture-line and in its deep constrictions. According to Haug,[6] however, the deep constrictions and prominent bulges which characterize the typical figure of Kudernatsch's appear only on the larger whorls. The umbilicus also seems to close with age, for in a specimen of 210 mm. diameter, quoted by Pompeckj,[7] it amounts to only 5 per cent of the diameter.

There is a resemblance to the forms figured by Vacek [8] as *Phylloceras ultramontanum* Zittel, but in that group the constrictions are more angular on the lateral area, and the elements of the suture-line are very simple and plump. This latter character also distinguishes the specimen under consideration from *Ph. mediterraneum* Neumayr, which occurs in the *macrocephalus* beds of

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[1] = *Ph. tatricum* (Pusch) in d'Orbigny, Ter. Jurass., pl. 180 (Oppel, *Pal. Mitt.*, 1863, p. 216).

[2] Loc. cit., 1910, p. 259.

[3] *La Faune du Callovien des Deux-Sèvres*, 1915, p. 89.

[4] "Études sur les Moll. et Brach. de l'Oxf. Inf. d. Jura Lédonien": Mém. Soc. Pal. Suisse, vol. xxvii, 1900, p. 11, pl. i, figs. 1, 2; pl. ii, fig. 1.

[5] Loc. cit., 1910, pl. v, figs. 3*a*, 3*b*.

[6] Loc. cit., 1891, pp. 70, 73.

[7] Loc. cit., Revision, 1893, p. 32.

[8] Loc. cit., 1886, pl. v, figs. 15–20.

India and Madagascar, though the writer found closely comparable ammonites in abundance in the Argovian beds of Jebel Zaghuan, Tunis.[1] The first lateral saddle is trifid in this species as in the East African specimen, but the simple folioles of the saddles represented in the figures of Popovici-Hatzeg[2] and Prinz[3] are quite different. On the other hand, it appears that, as in the case of *Ph. disputabile*, the many references to *Ph. mediterraneum* given in palæontological literature probably include a variety of evolute *Phylloceras* of the *ultramontanum* group,[4] and of the *Capitanei* group in the case of *Ph. disputabile*. It has already been mentioned that though the course of constrictions cannot accurately be determined, the specimen under consideration probably belongs to this *Capitanei* assemblage.

The rectangular section of the specimen here described might suggest connexion with the genus *Sowerbyceras*. The suture-line, however, is sufficiently distinct from that of this genus.

Horizon and Distribution.—*Phylloceras disputabile* is a Bathonian form, and occurs (generally associated with *Ph. Kudernatschi*, *Protetragonites tripartitum*, etc.) in the South of France, the Italian Alps, at Swinitza in Hungary, in the Carpathians, the Caucasus. It has also been recorded from the "Callovian" (zone of *M. macrocephalus*) of East Africa and India, and Haug[5] has it already in the Bajocian (zones of "*Sonninia*" *Romani* and "*Cosmoceras*" *subfurcatum*) of the South of France.

Locality.—No. 10, from the grey, otherwise unfossiliferous limestone beside the break-pressure tank, mile $\frac{1}{11}$ on the Mombasa pipeline (together with *Sowerbyceras* sp. aff. *tortisulcato* d'Orbigny sp.).

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[1] "Jurassic Ammonites from Jebel Zaghuan": Q.J.G.S., vol. lxix, 1913, p. 561.

[2] Loc. cit., 1905, text-fig. 6 on p. 15.

[3] Loc. cit., 1904, pl. xxxvi, fig. 8.

[4] Hochstetter (loc. cit., p. 142) states that *Ph. mediterraneum* begins in the Klaus Beds and ranges into the Tithonian. This vertical range is unusually great for a species group, even of a *Phylloceras*.

[5] Loc. cit., pp. 70, 73.

(*To be continued.*)

On the Investigation of the Mechanical Constitution of Loose Arenaceous Sediments by the method of Elutriation, with special reference to the Thanet Beds of the Southern Side of the London Basin.

By Herbert Arthur Baker, M.Sc., F.G.S.

THE mechanical constitution of a detrital sedimentary deposit is the aggregate result of the operation of a complex suite of physical laws which govern transport of detrital material by, and its deposition from, water in motion. These physical laws have been elaborately investigated by many workers, and while much remains obscure, important conclusions have been achieved. The detailed examination of the mechanical constitution of the sediments of the geological column has been neglected, although a few pioneer workers have obtained notable results. Sediments of economic value have received attention, but in the realm of pure geology workers have been slow to take up the investigation. Accumulating results indicate, however, that geologists would do well to devote attention to this line of research. Distinctive results are being obtained from sediments, which, even though they may not lend themselves at the present time to complete interpretation, from the point of view of reconstruction of the conditions under which the said deposits were formed, nevertheless bid fair to provide the geologist with another weapon in his armoury. Fluviatile deposits have been found to possess a mechanical constitution distinct from that of estuarine sediments, and the latter are again clearly differentiated, mechanically, from purely marine formations. It may be remarked, too, that the nomenclature in current use applied to the loose sedimentary deposits lacks that element of scientific precision so desirable and necessary if proper progress is to be made. Such terms as " sand ", " clayey sand ", " sandy clay ", and " clay " are at present employed by different writers in different senses, and some system of classification which would give definiteness to the meaning of these and similar terms appears to be urgently called for. The only satisfactory basis for such a classification must be a quantitative one, depending upon mechanical analyses of sediments. When a sufficiently comprehensive collection of comparative data is available it should be a simple matter to devise an adequate scheme for the classification of the loose detrital sediments.

With regard to the classification into grades, according to size, of the material which is liable to occur in any one sediment, a scheme which gives good results in practice is in current use. It is as follows:—

> 2 mm. diameter			Gravel grade.
> 1 ,, < 2 ,,	,,	Very coarse sand	Sand grade.
> 0·5 ,, < 1 ,,	,,	Coarse sand	
> 0·25 ,, < 0·5 ,,	,,	Medium sand	
> 0·1 ,, < 0·25 ,,	,,	Fine sand	
> 0·05 ,, < 0·1 ,,	,,	Coarse silt	Silt grade.
> 0·01 ,, < 0·05 ,,	,,	Fine silt	
< 0·01 ,,	,,		Clay grade.

Deposits consisting wholly of material of one or other of the grades specified above do not appear to occur in nature. Detrital sediments consist of a mixture of certain proportions by weight of many of the above grades, and it is the purpose of a mechanical analysis to determine the proportionate weights of the grades present in the sediment under examination. The allocation of a descriptive name to a sediment depends, usually, upon the presence in it of some one particular grade which occurs in sufficiently marked preponderance to influence the general character of the whole. But proportionality of the various grades is often of great importance in influencing the nature of a sediment, especially in the case of the finer arenaceous deposits. A sandy sediment may contain a percentage-weight of the clay grade, which, though small, is nevertheless enough to bring up the capillarity and water-capacity of the whole to a value sufficient to result in considerable binding-power. Such a sediment, when seen wet, in the field, would be liable to be termed "clay", although the same material, seen dry, in the laboratory, would probably be termed "sand". These points emphasize the need for a definite classification of sediments, based fundamentally upon the grades present and the proportionality by weight of these grades.

Early in 1919 the opportunity was afforded the present writer of undertaking, at the Imperial College of Science and Technology, a piece of work which he had long had in mind, namely, a study of the Lower London Tertiary strata of the southern side of the London Basin. The sediments to be dealt with being in the main arenaceous, it appeared likely that useful results would be afforded by detailed mechanical analyses. Professor P. G. H. Boswell had found such analytical data of much service in his study of various deposits (including the Lower London Tertiaries) in East Anglia, and had further shown the great value of such work upon sediments from the economic point of view. Accordingly much time was spent in carrying out a very large number of careful mechanical analyses, and the opportunity was taken of revising the methods of experiment in this connexion. From results obtained, the writer is convinced of the usefulness and importance of this line of work to geologists, and hopes that it will receive the attention which it deserves at the hands of future workers.

It is proposed in the present paper to deal with some points connected with the revised methods of experiment in carrying out mechanical analyses, and to give, in outline, the main results arising from this side of the writer's investigations, so far as the Thanet Beds alone are concerned.

All the data were obtained by elutriating samples of the various sediments in glass tubes of a special shape, by means of upward currents of water at known speeds. Sifting, by means of meshes and sieves, was not resorted to for the following reasons: (1) The data obtained by the use of sieves are not truly comparable with results given by the employment of currents of water, owing to the different behaviour of the individual grains in the two cases. A grain may be considered as possessing three dimensions at right angles to each other, a maximum, a minimum, and an intermediate dimension. When placed on a sieve it is the intermediate dimension which decides whether the grain pass the sieve or not, since, if this permit, the grain will turn up on end and drop through the sieve. When buoyed up by a current of water the grain turns so as to expose its greatest cross-sectional area to the current, and consequently, in this case, the maximum dimension, as well as the intermediate one, is of large account in deciding whether the grain shall remain in the tube or be washed off. (2) Meshes and sieves, especially fine ones, are liable to be inaccurate. It is not easy to obtain a sieve of any specified gauge, and the apertures in any sieve, especially after a little wear and tear, show a serious variation among themselves. (3) Sieves are very liable to become clogged up. This frequently occurs during a sifting process, so that even after prolonged agitation of the sieves large amounts of fine material will yet remain entangled within the meshes of even coarse sieves.

ELUTRIATION BY WATER CURRENTS:[1] (1) PHYSICAL BASIS OF THE METHOD.

When mineral grains are allowed to settle freely in a liquid they do so under the influence of gravity, but the rate of subsidence

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[1] General accounts of the method of conducting elutriation experiments have been given by Crook and also by Boswell. For these and for other information concerning the process, consult the following:—

(1) Crook, Appendix to Hatch & Rastall, *Sedimentary Rocks*, London, 1913, p. 349.

(2) Boswell, *British Resources of Sands and Rocks used in Glass-making*, 2nd (complete) ed., London, Longmans, Green & Co., 1918.

(3) Boswell, *British Resources of Refractory Sands for Furnace and Foundry Purposes*, London, Taylor & Francis, 1918.

(4) Stadler, "Grading Analyses by Elutriation": Trans. Inst. Min. and Metall., xii, 1912–13, p. 686.

(5) Keilhack, *Lehrbuch der praktischen Geologie*, 1908, 2nd ed., Stuttgart.

(6) Ries, *Clays, their Occurrence, Properties, and Uses*, 2nd ed., New York, 1908.

of any specified grain is controlled by its size, specific gravity, and shape, as well as by the density and viscosity of the liquid in which it is subsiding. Experimental work has shown that the size or surface-area of the grains is the dominant controlling factor, and is of much more account than specific gravity in the case of small particles. Where the aggregation of grains consists largely of variously sized fragments of the same mineral, as, for example, in a quartz sand, the difference of "free-settling velocity" or "hydraulic value" of the grains affords a convenient means of classifying them according to size. Although increase of temperature diminishes both the density and the viscosity of the water which is sorting the grains it is possible to apply an appropriate correction to counterbalance these variations. The process of elutriating by means of currents of water is based upon the fundamental assumption (which is justified by results) that the final velocity of subsidence of a grain is that of the upward current of water which will just keep it in suspension. Laborious experimental work on the relation between diameter of grains and rate of free settling in water has been carried out in the case of the mineral quartz, and has yielded data upon which the elutriation process is based. Loose arenaceous sediments, being composed very largely of quartz grains, can be classified into grades down to, and below, material of ·01 mm. diameter, and if necessary up to about 12 mm. diameter, and in the separation of any specified grade the experimenter may make the minimum and maximum limits of size as narrow as he pleases.

From the purely mathematical point of view the problem of the subsidence of a small sphere in a fluid medium was investigated by Sir G. G. Stokes.

If a small particle, assumed spherical, of density ρ_1 and radius a fall through a fluid of density ρ and viscosity μ, and at rest, it will be accelerated at first. This acceleration is not, however, constant, but decreases with increasing speed, so that the particle, if afforded the opportunity, eventually moves uniformly with velocity

$$U = \frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot ga^2.$$

If the particle is at the bottom of an elutriator tube and it encounters an upward current of water of velocity V, it will initially begin to move up with the water with the same velocity. But gravity will retard it, and it will suffer a negative acceleration. Consequently its speed will be reduced, and it will ultimately, if afforded the opportunity, move upward with velocity

$$V - U = V - \frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot ga^2.$$

If $V = \frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot ga^2$ the particle will cease to rise after the steady state has been attained.

If $V < \frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot ga^2$ it will fall again, and so will not be washed off.

If $V > \frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot ga^2$ the particle will be washed off.

Thus, the critical point at which washing off just ceases will be when

$$V = \frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot ga^2.$$

For a spherical grain of a specified mineral, falling through a specified liquid at a specified temperature,

$$\frac{2}{9} \cdot \frac{\rho_1 - \rho}{\mu} \cdot g = \text{a constant},$$

consequently we have

$$V = kD^2,$$

where V is the upward velocity of the water current,
k is a constant, and
D is the diameter of the grain.

This is known as the law of Viscous Resistance. R. H. Richards,[1] experimenting on ordinary quartz grains, considered this law to hold approximately for grains not exceeding about ·2 mm. diameter. The character of Richards' results suggests, however, that he made no allowance for temperature changes in the water in which the grains were subsiding. (See plot of Richards' results, Fig. 1.) In the light of later research work by another investigator it is now known that the law of viscous resistance does not hold closely for even small grains.

For larger particles and greater velocities it has been suggested that the rate of subsidence might conform to the law

$$R = kV^2$$

where R is the resistance to motion and k is a constant.

This was suggested by Newton, and hence the law is sometimes referred to as Newton's Law of Eddying Resistance. In the case where dynamic equilibrium exists between the particle and the liquid resisting its subsidence, R is just equal to the effective weight of the particle in the liquid. Rittinger considered that the formula

$$V = C\sqrt{D(\delta - 1)}$$

where C is a constant,
D is diameter of mineral grain, and
δ is specific gravity of mineral,

was applicable to the case of mineral grains settling in water. Richards found that Rittinger's formula held with tolerable accuracy for grains exceeding 1·55 mm. diameter, but below this limit the value of Rittinger's C decreased rapidly.

---

[1] Richards, *Textbook of Ore Dressing*, 1909, pp. 262–76.

Hence, for grains of a specified mineral, exceeding about 1·55 mm. diameter, subsiding in water at constant temperature, we have

$$V = k\sqrt{D} \text{ where } k \text{ is a constant.}$$

Richards found that this Law of Eddying Resistance is more nearly true the greater the velocity; that is, when the true viscous resistance plays a continuously less important part, and the eddying resistance an increasingly important part. If we take the value for the constant k as indicated by Richards' work, we find that the velocities calculated from the formula for grains between ·2 and ·5 mm. diameter are too great. In the plot shown on the graph (see Fig. 1) of the Law of Eddying Resistance the related values assumed for the purpose of determining k were ·327 mm. for D and 36·12 mm. per second for V, for the temperature of 15° C., other independent work having indicated the reliability of these figures. Even with the introduction of this modification of Richards' k it can be seen from Fig. 1 that Richards' results, for grains between about ·2 mm. and ·5 mm. diameter, do not agree closely with this theoretical law of eddying resistance.

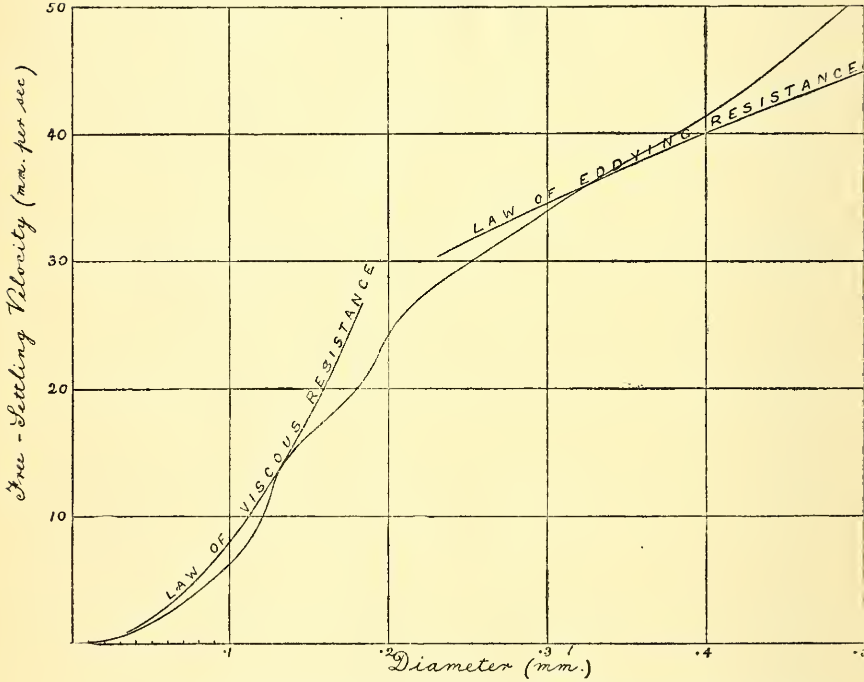

Fig. 1.—Plot of Richards' data on the free-settling velocities in water of quartz grains less than ·5 mm. diameter. With plots of the laws of viscous and eddying resistance inserted for comparison.

In elutriation work on arenaceous sediments it is important for the investigator to know accurately the rate of settling of quartz grains between the limits of ·01 mm. and about ·4 mm. diameter. This matter has recently been made the subject of careful investigation by another worker, who very kindly permitted the present writer to make use of his results (which are as yet unpublished) in the carrying-out of mechanical analyses. It is not fitting to discuss here the unpublished work of another, but the writer may, perhaps, be permitted to state that the behaviour of subsiding grains, between the limits of ·2 mm. and ·5 mm. diameter, shows no closer adherence to the law of eddying resistance than does that of grains between the limits of ·01 mm. and ·2 mm. diameter to the law of viscous resistance. In fact, the rates of subsidence of grains between the limits of ·01 mm. and ·4 mm. diameter vary in a definite way, which is very clearly a compromise between these two laws.

In the absence of published information concerning this later research, which is of fundamental importance to workers interested in the mechanical analysis of sediments, it may be remarked that the data are of such a character as to lend themselves to mathematical expression in the form of formulæ. A series of formulæ, by means of which the rate of subsidence in water of a quartz grain can be calculated, when the diameter of the grain and the temperature of the water are known, has been worked out by the present writer, who hopes, at a later stage, to collaborate with the author of the research in discussing this point.

(2) CONDUCT OF ELUTRIATION EXPERIMENTS.

The reasons for rejecting the rapidly working, two-tubed Crook elutriator in favour of the more tedious Schoëne single-tube process may be stated. The Crook elutriator possesses the advantage of effecting the separation of a sample into three grades in one operation. The disadvantages, however, far outweigh this initial gain. The Crook elutriator consists of a pair of tubes, one below the other, the water passing from the lower, smaller tube to the upper, wide tube, and thence escaping from the jet-tube carried by the latter. The diameters of the two tubes are adjusted to each other and to the water-supply in such a way that the total sand-grade (>·1 mm.) in the sample under examination is retained in the lower tube, the total silt grade (0·01 to 0·1 mm.) is retained in the upper tube, and the clay grade (<·01 mm.) is washed away. A practical difficulty which meets one at the outset is the matter of adjusting the diameters of the two tubes so as to preserve the correct ratio between them. It is only by chance that tubes of precisely the diameters required can be secured, and in the Crook elutriator, as set up in laboratories, the adjustment is usually more or less approximate.

The flow of a liquid through a tube is either of the steady, irrotational type, in which the liquid is moving in cylindrical layers coaxial with the axis of the tube, and the layer of liquid against the wall of the tube is at rest, or of the rotational, eddying type, in which the velocity of the current is more or less uniform over a large part of the cross section of the tube. To obtain the first type of flow certain preliminary precautions must be taken, but in the case of the current of water passing through an elutriator these precautions are ignored, so that we have to deal with the case of eddying flow. The tube wall has an important retarding effect upon the current, and the ratio of the circumference of a tube to its cross section varies inversely as the diameter. Osborne Reynolds has stated that the critical mean velocity at which the steady type of flow breaks up and is replaced by eddying flow varies inversely as the diameter of the tube. Hence, with so narrow a tube as the smaller tube of a Crook elutriator there is a much stronger tendency for the flow to approximate to the steady, irrotational type than in the case of a fairly wide tube. For the steady, irrotational type of flow the formula

$$v = \frac{2Q}{\pi a^4}(a^2 - r^2) \text{ applies}$$

where v = velocity at a point distant r from axis of tube,
Q = volume passing a cross section of the tube in unit time (or outflowing from jet in unit time),
a = radius of tube.

In the centre of the tube $r = o$, consequently

$$v = \frac{2Q}{\pi a^2}$$

and since $\frac{Q}{\pi a^2}$ is the average velocity of the current, as calculated from the outflow from the jet, it follows that, in the centre of the tube the velocity of the current is *twice* as fast as the calculated average. Therefore, in the smaller tube of a Crook elutriator, although the conditions requisite for steady, irrotational flow are not completely realized, the velocity of the current in the centre of the tube is approaching double the value of the mean speed for which the apparatus has been adjusted. Hence much material will be washed off which should be retained within the tube, and a mechanical analysis, effected by means of a Crook elutriator, will always give too low a percentage weight for the sand grade, and too high a percentage weight for the silt grade. The seriousness of the error involved is seen at once from the following comparative results, which are selected from a number of tests made by the writer :—

	CLAY.	SILT.		SAND.			
	mm. <·01	mm. >·01 <·05	mm. >·05 <·1	mm. >·1 <·125	mm. >·125 <·15	mm. >·15	
	% wt.	% wt.	% wt.	% wt.	% wt.	% wt.	
Thanet Sand (upper part), Knee Hill, Abbey Wood.	5·64	2·37	12·10	37·00	39·67	3·22	By single-tube method.
		14·47		79·89			
	5·23	38·72		56·05			By Crook elutriator.
Woolwich Beds (basement loam), Charlton Pit.	26·20	11·07	12·17	33·07	15·85	1·64	By single-tube method.
		23·24		50·56			
	26·45	29·15		44·40			By Crook elutriator.

If the lower tube of the Crook elutriator were increased in diameter the upper tube would assume very unwieldy proportions.

Two other disadvantages of the Crook elutriator may be mentioned. The sample is separated into three grades only. Consequently, when the attempt is made to express the result of a mechanical analysis graphically, by means of a curve, the data are insufficient. Further, the elutriation curves of arenaceous sediments are now known to be of such a character that, for the purpose of obtaining accurate and reliable curves, grade divisions are required to be effected at points which this apparatus does not determine. In attempting to overcome this by employing more than two tubes, the original difficulty of adjusting the required tube-diameters correctly becomes insurmountable. In addition, it is not possible, when using a Crook elutriator, to apply a correction for, or make any adjustment to counteract, changes of temperature in the water passing through the apparatus, although this can readily be done when the single-tube method is employed. The temperature correction is a large one, and the ignoring of it is liable to lead to serious error, particularly in the case of the finer sediments.

The mechanical analyses made by the writer were carried out on samples of about 40 grammes weight, preliminary trials having shown this quantity of sediment to be well suited to the capacities of the tubes employed. The latter ranged in diameter from about 3·75 inches down to about 1 inch. Bearing in mind the value of graphical representations of the analyses obtained, preliminary experiments were made in order to ascertain the general character of the curves given by arenaceous sediments, so that the separations might be effected at points where the latter were most required for curve-plotting purposes.

The elutriator tubes employed by the writer are fitted with specially made glass stoppers, which are ground so as to fit well, and always to enter the tube to the same depth. The stopper carries two short tubes, to one of which is attached the jet-tube and to the other the manometer-tube, carrying a graduated scale, intended for use with a particular jet. By having corresponding pairs of jets and graduated manometer-tubes, the same elutriator-tube may be used repeatedly in carrying out different parts of the mechanical analysis. In setting up the apparatus for the first time a jet and ungraduated manometer-tube are attached, and the water turned on. The flow is controlled by means of the screw-clip on the fairly thick-walled rubber connexion attached to the lower end of the elutriator-tube. With the water standing at some arbitrary point low down in the manometer-tube, the outflow, in cubic centimetres per minute from the jet, is determined by means of graduated measure and chronometer. This point is marked and the current then increased, so that the water stands at a higher point in the manometer-tube, when a fresh determination of the outflow per minute is made. Proceeding in this way a series of readings is obtained, which when plotted on a graph are found to lie on a smooth curve, by means of which the manometer scale can be constructed. This scale, therefore, indicates from the height of the water in the manometer-tube, the volume in cubic centimetres per minute flowing through the elutriator when the appropriate jet is being used.

A graph is constructed, showing for each elutriator-tube in use the relation between the rate of outflow from the jet, in cubic centimetres per minute, and the mean rate of the upward current in the tube in millimetres per second. The graphs for all the tubes can be conveniently represented on the same diagram—they are, of course, straight lines.

In proceeding to make a separation of a sample at some specified limit of diameter, the first step is to take the temperature of the water which is to be used. Knowing this, the appropriate rate of current is next ascertained. Then, on consulting the graph for the elutriator-tube which it is proposed to use, the rate of outflow from the jet required to give this current is readily obtained. It then only remains to select a suitable jet and corresponding graduated manometer-tube for attachment to the apparatus.

The separation of a sediment into a large number of grades is a tedious business, and much valuable time is often lost in removing from the elutriator, drying, and weighing the successive remainders as grade after grade is washed off the sample. In order to facilitate the progress of the analysis the writer has devised the following method of procedure which obviates the necessity of removing and drying the material at the completion of each stage of the process. It is necessary to know at the outset the weight of the empty elutriator-tube together with its rubber connexion and screw-clip at the bottom, but without the stopper and its adjuncts. A weighing is taken before the elutriation is commenced, of tube and contents, when the sample is in the tube and the remainder of the tube is filled with water up to the level to which the bottom of the stopper reaches. The weighing can conveniently be obtained by means of a large specific gravity balance having one of the pans at a higher level than the other and equipped with a hook underneath. After the elutriation another weighing of tube and contents is taken, and the next stage in the analysis can be proceeded with immediately, whilst the weight of sediment remaining in the tube at the end of the previous stage is being calculated. This required weight is calculated from a formula which is obtained as follows :—

Before elutriation	Let weight of sediment in tube	$= a$ gms.
	Let weight of water in tube	$= b$,,
After elutriation	Let weight of sediment in tube	$= c$,,
	Let weight of water in tube	$= d$,,

a is known when put in, and total weight of contents is found, hence $b =$ total weight contents $- a$.

The total weight $c + d$ is found by weighing.

Put $c + d = x$; then $d = x - c$.

Now the total volume of sediment and water remains the same at the end of the experiment as it was at the beginning.

Put $\rho_1 =$ density of water used, and

$\rho_2 =$ density of sediment.

Take $\rho_2 = 2{\cdot}65$ (treating the sediment as a pure quartz sand).

Then volume before elutriation $= \dfrac{a}{2{\cdot}65} + \dfrac{b}{\rho_1}$ cu. cm.

and volume after elutriation $= \dfrac{c}{2{\cdot}65} + \dfrac{d}{\rho_1}$ cu. cm.

$$\therefore \quad \frac{a}{2{\cdot}65} + \frac{b}{\rho_1} = \frac{c}{2{\cdot}65} + \frac{d}{\rho_1}$$

i.e. $a\rho_1 + 2{\cdot}65b = c\rho_1 + 2{\cdot}65d$,

and substituting $x - c$ for d, we get

$$a\rho_1 + 2{\cdot}65b = c\rho_1 + 2{\cdot}65x - 2{\cdot}65c.$$

$$\text{Hence } c = \frac{2{\cdot}65\,(x - b) - a\rho_1}{2{\cdot}65 - \rho_1}$$

The formula gives very good results, since a, x, and b are all determined by weighing, and the error involved by taking the density of the sediment as 2·65 is very small, since arenaceous sediments are very largely quartzose. For the value of ρ_1 appropriate to the temperature of the water at the time of the experiment, it is convenient to consult a graph showing the variation of the density of the water in use with change of temperature. This graph can be constructed from the results of preliminary experiments on the water. It may be remarked, however, that an error in the determination of ρ_1 considerably greater than the experimenter is likely to make in practice, introduces only an insignificant error into the final evaluation of c. It is well, however, to be as accurate as possible, since errors in the determination of c are accumulative, the c of one stage of the analysis becoming the a of the next.

In the earlier stages of an analysis, when washing off the very finest material, the method outlined above is not practicable. Wide and heavy tubes, such as cannot be suspended from the arm of a laboratory balance, are usually then in use. Moreover, much of the material removed consists of clay or lithomarge, hydrated silicate of alumina, and consequently the figure 2·65 for its density is inadmissible. The writer determined the mean densities of a number of Lower Tertiary sands of different types, and found that in sand containing a fair percentage-weight of the clay grade the average density dropped rather markedly. A quartz sand containing 4 per cent by weight of clay has an average density of 2·60, and the average density decreases below this figure at about ·0015 for every 1 per cent weight increase of the clay grade. A quartz sand with 20 per cent by weight of clay has an average density of 2·574. The Lower Tertiary sands, when washed free from clay, had the same density as quartz (2·65).

Another method, which avoids loss of time in the drying of residues, is as follows: On the completion of a stage of the elutriation process the residue is run out from the tube into a glass flask filled to a mark on the neck with water. The weight of water required to fill the flask to the mark is known. When the sediment is in the flask the water displaced by it is removed, so that the water stands at the mark once more. A weighing is then taken. The difference between weight of sediment with water to mark and weight of water to mark gives the weight of the sediment *in water*. The weight of this sediment, when dry, is then calculated from the formula:—

$$\text{Weight (gms.)} = \frac{d}{d-1} \times \text{weight in water (gms.)}$$

where d = density of the material.

As already stated, if the clay material has been removed from the sample, the density of arenaceous deposits may safely be taken as 2·65. The above formula assumes the density of the water to be 1, but the error involved is negligible in practice.

This method is particularly useful when elutriating arenaceous sediments after the clayey material has been removed. It is then very convenient to calculate the initial weight of sediment from the formula given above. If an initial weight of 40·15 gm. be taken this will weigh exactly 25 gm. in water, and the successive weights in water obtained afterwards have only to be multiplied by four in order to give percentages.

(*To be continued.*)

REVIEWS.

Geology of the Yangtse Estuary below Wuhu. By V. K. Ting. Whangpoo Conservancy Board. Shanghai Harbour Investigation, Series 1, No. 1. pp. 84. Shanghai, 1919.

THIS work is divided into four sections, dealing with (1) stratigraphy, (2) structural geology, (3) physiography, and (4) history of the Yangtse Estuary.

The greater number of the deposits are Palæozoic, the earliest fossiliferous beds having yielded an Ordovician fauna. These are succeeded by quartzites doubtfully referred to the Devonian system. The Carboniferous is divided into Lower and Upper Carboniferous Limestones, with Middle Carboniferous containing the Nankao Coal series between. The Lungtan Coal series is referred to the Permian, and a succeeding limestone to the Permian or Triassic system. No undoubted Mesozoic rocks have been determined in the area, though the strata of another coal-bearing group at no great distance away have yielded a fossil flora thought to be undoubtedly of Rhætic age. The next deposit in order of age is the Tat'ung conglomerate of Tertiary age, concerning the formation of which there is a difference of opinion. The question is discussed by the author. Upon this conglomerate reposes loess, which is the newest deposit except the alluvium.

An account of the igneous rocks includes descriptions of granites, intrusive porphyritic rocks, rhyolitic and trachytic lavas, and basalts.

The structural section deals with the tectonics of the region. A general account of the physiography follows. The historical sketch treats of the question of the theory of ancient mouths of the Yangtse, the growth of its delta in historic times, and the origin of the Whangpoo River.

The area forms part of the ground traversed by Richthofen, whose work is recorded, but much that is new is added, and some of Richthofen's views are criticized.

The work is illustrated by a coloured folding map of the geology, many other geological maps and sections, and photographic illustrations, and is a valuable description of an area by an up-to-date geologist.

The work was undertaken for a specific purpose, the investigation of the hydrography of the Yangtse Estuary. We look forward to the production of important geological memoirs of other areas by Mr. Ting (who is Director of the Government Geological Survey) and his assistant surveyors.

J. E. M.

DIAGNOSTIC CHARACTERISTICS OF MARINE CLASTICS. By E. M. KINDLE. Bull. Geol. Soc America, vol. xxviii, pp. 905–16. 1917.

THE author of this paper is very deeply and rightly impressed with the truth of the saying that "the present is the key to the past". He therefore brings forward some of his observations of phenomena in present-day sediments which may be of use in deciding whether rocks are of marine or freshwater origin. The points considered are (1) the behaviour of fine sediment in fresh and salt water, (2) the surface markings and textures developed during sedimentation and during desiccation of muds, and (3) the distinguishing characters of ripple-marks. In the first place it is noticed that alternating layers of sandy and muddy material deposited in salt water have more sharply defined boundaries than those laid down in fresh water, owing to the comparatively rapid flocculation of very fine sediment in salt water.

Passing to the second section, it is explained that this flocculation of clay is accompanied by small vertical currents, and that these cause structures known as "pit and mound structures" on the surface of the deposit. Structures produced during desiccation are also different in freshwater and salt-water muds; the "sun cracks" of salt-water muds have level or turned down edges, while the edges of these cracks formed in freshwater muds are turned up. Further, the texture of a dried saline mud is vesicular, and thus quite unlike that of a freshwater mud. The question of ripple-marks is discussed at some length, and the author draws distinctions between those due to current action and those due to wave action without forward movement. The former type will be found to predominate in tidal seas, while the latter is more prevalent in inland lakes; it is also noted that the ripple-marks produced by rivers will show evidence of motion in one direction only, while those due to tidal currents will indicate motion in at least two opposite directions. Though in the opinion of the reviewer the author appears to be somewhat over-sanguine, yet the points advanced in this paper seem to be worthy of serious consideration when working through series of sediments of doubtful origin.

W. H. W.

THE MINERAL DEPOSITS OF SOUTH AMERICA. By B. L. MILLER and J. T. SINGEWALD, jun. pp. ix + 598, with 61 figures. New York: McGraw-Hill Book Co., Inc. London: Hill Publishing Co., Ltd. 1919. Price 25*s*.

WE cordially welcome this book, inasmuch as it gives us for the first time a collected and accessible account of the great mineral wealth of the South American Continent, from which came so much of the fabled wealth of the Spanish galleons. The amount of detailed information contained in these pages is astonishing, and though written in somewhat more prosaic style than the stories of the early adventurers, it is equally interesting, perhaps more so to an economic geologist, since the romance is here founded on fact.

The first chapter contains an admirable description of the general physiographical and geological features of South America, with a discussion of tectonics and their bearing on the problems of mineralization. The country is divided into eight districts—the Guianan Highlands, the Brazilian Highlands, the Cordilleras, the Llanos and the plains of the Orinoco, the plains of the Amazon, the plains of the Paraguay and Paraná, the Patagonian Pampas, and the coastal plains. Nearly all the economic minerals are contained in the first three.

Each of the succeeding eleven chapters contains a full and comprehensive account of the economic geology of one of the South American States, a large part of the information being the result of personal observations by the authors, especially in Brazil, Chile, Bolivia, and Peru, and in part in Argentina, Ecuador, and Uruguay. Each chapter closes with an admirable bibliography, which in some cases include over 200 items. This is an invaluable feature of the book.

Among so many points of interest it is difficult to make a selection for special mention. One of the most fascinating chapters is that on Bolivia, where the rich silver-tin-tungsten mineralization naturally comes in for a large share of attention, both on account of its intrinsic value and for its theoretical significance. It is refreshing to read a clear and coherent account of these important deposits as they really are, freed from the absurd generalizations of the Freiberg school. The Bolivian silver-tin deposits seem to form a well-authenticated example of the occurrence of tin and tungsten in quantity in connexion with Tertiary igneous activity. It is noteworthy, however, that as soon as the frontier of Argentina is crossed the minerals are clearly associated with Palæozoic granites. Hence we have here an instance of the occurrence of a similar type of mineralization in two neighbouring areas at two widely separated periods of time. It is as yet too early to say definitely whether there is any overlap of these two mineralizations in space.

A very full account is given of the iron and manganese resources of Brazil; the former are undoubtedly enormous, some good authorities having estimated the reserves of hæmatite in the State of Minas Geraes alone at 12,000,000,000 tons. This is probably excessive, but it is clear that Brazil contains the most important undeveloped deposits of iron-ore of any country in the world. However, development is hindered by difficulties of transport, owing largely to the absence of important coalfields and the remoteness of the iron districts from the coast The magnetite ores of Jacupiranga, described by Derby, are of great petrographic interest, since they are derived from a highly alkaline syenitic magma. Manganese is now the most important of the mineral products of Brazil, and in 1916 the production was nearly half a million tons, mostly shipped to the United States, replacing supplies formerly obtained from India and Russia.

It is impossible in the space at our disposal to mention even a tithe of the interesting facts connected with the mineral wealth of South America, both developed and undeveloped; we can only advise all geologists who feel any interest in the economic side of their subject to read this book, which is indispensable to the practical man, and contains a mine of information of value to those dealing with the geology of all mineral products, metalliferous and non-metalliferous, salts, coal, oil, and gems.

R. H. RASTALL.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN. VOL VI: REFRACTORY MATERIALS. 2nd edition. Mem. Geol. Survey. pp. vi + 241, with 3 plates and 8 text-figures. 1920. Price 7*s*. 6*d*. net.

THE first edition of this memoir, published in 1917, was reviewed at some length in this Magazine, and this edition does not show many changes; a few small corrections have been made, but in the main the descriptions remain as before; the field-staff has been engaged on other work, and no re-examination of the mines and quarries was found possible. We trust that this does not mean that the volumes of this most useful series will not be kept up to date by frequent revision, as has been anticipated. It is, however, satisfactory to find that another volume is in the press giving the chemical analyses, petrological description, and results of refractory tests of the materials here described. This will add much to the value of the present work.

EARTHQUAKES IN OREGON. By WARREN DUPRÉ SMITH. Bulletin of the Seismological Society of America, vol. ix, 1919, pp. 59–71.

THOUGH sometimes supposed to be immune from earthquakes, the State of Oregon, as this short paper shows, has been disturbed by thirty earthquakes during about the last seventy years, most of them slight, but among them were two strong enough to damage buildings. The records are, however, too scanty to lead to results of much scientific value.

C. D.

INDIAN GEOLOGICAL SURVEY DEPARTMENT.

THE Secretary of State for India proposes to make four appointments to the Indian Geological Survey Department in August this year if so many qualified candidates are available. Preference will be given to candidates who have served in His Majesty's Forces during the War. Besides a good general education, a sound education in geology is essential. A University degree and a knowledge of French or German will be regarded as important qualifications. Candidates should not be more than 25 years of age, but this rule may be relaxed in exceptional cases. Detailed regulations and forms of application may be obtained from the REVENUE SECRETARY, India Office, London, S.W. 1. Applications for appointment must be received not later than 1st August, 1920.

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All Communications for the EDITOR should be addressed to

R. H. RASTALL, Esq., M.A., Christ's College, Cambridge.

All letters for Dr. H. WOODWARD, F.R.S., may be sent to

Tudor Cottage, Clay Hill, Bushey, Herts.

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HENRY WOODWARD, LL.D., F.R.S.
AND
R. H. RASTALL, M.A.

ASSISTED BY
PROF. J. W. GREGORY, D.SC., F.R.S.
F. H. HATCH, PH.D., M.INST.M.M.
PROF. J. E. MARR, SC.D., F.R.S.
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HENRY WOODS, M.A., F.R.S.
DR. A. SMITH WOODWARD, F.R.S.

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EDITORIAL NOTES.

SIR AUBREY STRAHAN, K.B.E., Sc.D., LL.D., F.R.S., retired in July from the post of Director of the Geological Survey. He is succeeded by Dr. J. S. Flett, O.B.E., F.R.S., who has hitherto been Assistant Director of the Scottish branch. Mr. G. W. Lamplugh, F.R.S., Assistant Director for England and Wales, lately President of the Geological Society of London, has also retired. from the Survey.

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We greatly regret to announce the death of Dr. Wheelton Hind, which took place on June 21 after a short illness. Owing to want of space an appreciation of his geological work is held over till next month. We have also in hand a paper by Dr. Hind on the Distribution of British Carboniferous Nautiloids, received only a few days before his death; this it is hoped to publish very shortly. Dr. A. Scott, of Stoke-upon-Trent, has kindly agreed to correct the proofs and see the paper through the press.

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The 88th annual meeting of the British Association for the Advancement of Science will be held at Cardiff from August 24 to August 28, 1920, under the presidency of Professor W. A. Herdman, C.B.E., D.Sc., Sc.D., LL.D., F.R.S., who will in his address give a general survey of Oceanography, and will deal with certain special problems in detail. The meetings of Section C (Geology) will be held in the Technical College. The president of this section will be Dr. F. A. Bather, F.R.S., and the secretaries are Dr. A. R. Dwerryhouse, Dr. W. T. Gordon, Dr. G. Hickling, and Professor A. H. Cox.

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The Geophysical meetings of the Royal Astronomical Society for next session have been fixed as follows: November 5, Geodesy; December 3, Terrestrial Magnetism; February 4, to be arranged; March 4, Seismology; May 6, Meteorology; June 17, Geodesy. All Fellows of the Geological Society are invited to attend, and fuller particulars will appear in *Nature*, or can be obtained on application to the Assistant Secretary, Royal Astronomical Society, Burlington House, W. 1.

We have received from the Yorkshire Geological Society a circular setting forth that the Society is anxious to develop the study of Yorkshire rivers along the lines that have proved so fruitful in America With their customary enterprise the Council have formulated a comprehensive scheme, for which they desire to enlist the aid of workers in all cognate sciences, whether members of the Society or not. As a matter of fact the work was begun in the Washburn valley last summer, and will be continued there, but it is hoped to extend it to other rivers throughout the county. The circular very wisely points out that a precise knowledge of tectonic structure is of fundamental importance in such a study, since this must affect the origin and evolution of the rivers ; hence workers are invited in the first instance to record with precision the dip of the rocks in their respective areas. This is not quite so easy as it sounds at first, as all field-workers are well aware, owing to landslips, surface-creep, current-bedding, and other causes which need not be specified here. The importance of a record of faults and dominant joints is also insisted on. Besides these purely geological points, information is also desirable as to records of rainfall and the heights attained by floods and their frequency. Recent experiences in Lincolnshire have demonstrated the geological potency of sudden floods. With regard to the actual carrying out of the work, it is proposed, wherever possible, to form local committees, and all those interested are invited to communicate with the Secretary, Mr. H. E. Wroot, Pollard Lane, Bradford.

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The Government has now introduced into Parliament the promised Bill for the establishment of a Ministry of Mines, and, frankly, it is a very disappointing document. It is a good point, in view of economy, that the Ministry is to be a Department of the Board of Trade and not entirely new and independent, but beyond this we find little to praise. The provisions of the Bill are almost entirely concerned with coal-mining, and non-ferrous mining is only once specifically mentioned. It is provided that the Minister *shall* appoint a committee to advise him regarding coal, and that he *may* appoint a similar one to deal with other mines and quarries. We must hope that the metalliferous mining industry will make its needs known with sufficient force in the proper quarters, so that more consideration may be shown to an important industry by the Act in its final shape.

ORIGINAL ARTICLES.

Beerbachite at the Lizard.

By Professor T. G. Bonney, Sc.D., F.R.S.

IN my paper on the Lizard this rock is mentioned, but without a specific name, for I had not then seen the figure given in 1898 by Rosenbusch (*Elemente der Gesteinslehre*, 1898, p. 51). He calls it Beerbachite, and describes it on p. 219 as one of his *Ganggesteine*, among those *von malchitischem Habitus*, quoting an analysis. The name appears to have been given by Chelius to a rock from Frankenstein in the northern Odenwald, where it forms small veins in a gabbro, and has the following analysis: $SiO_2 = 47·21$, $Al_2O_3 = 20·52$, $Fe_2O_3 = 7·48$, $FeO = 5·32$, $MgO = 4·16$, $CaO = 8·63$, $Na_2O = 5·17$, $K_2O = 0·33$, $H_2O = 0·34$, $P_2O_5 = 0·46$, with 0·19 FeS_2 and 0·10 hygroscopic water. He states that the rock is fine-grained to compact, not lustrous, grey to pale grey in colour, consisting of a panidiomorphic mixture of labradorite and diallage, with a variable amount of hypersthene and magnetite, and that olivine-bearing varieties occur. In these commonly a brown hornblende replaces the diallage, in which the above-named constituents are pœcilitic. He states that beerbachite also occurs in gabbro near Harzburg and in the Isle of Mull.

At the Lizard the best outcrops of the rock are near Luggar Cove, to the south of Porthoustock, and I call it in my diary for July 6, 1894, when I particularly studied that part of the coast, "the brown-speckled rock," but it occurs, sometimes in considerable force, from near St. Keverne to the neighbourhood of Porthallow,[1] and I observed and collected it, a few years earlier, from the crags north of the Balk, where, however, it is less well exposed and rather more weathered. The following shortened extract from my diary for 1894 (which is illustrated by sketches) may serve to show the curious mixture of rocks near the shore to the north of Crousa Down. In certain places the gabbro itself varies much, a coarse variety, with diallage crystals sometimes a couple of inches in diameter, occasionally appearing in irregular patches and even in little tongues in the finer gabbro. The "brown-speckled" rock breaks into the gabbro, including fragments, patches, and streaks of it, a few inches or even more in length and perhaps one to three in diameter, which often assume a foliated structure. The speckled rock also not seldom appears to be "porphyritic". The crystals, which may run to about

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[1] I studied the coast north of Crousa Down, from St. Keverne, in 1890, with my friends General McMahon and Canon Hill, and again in 1894 with the latter. I revisited it in 1908, when staying with Dr. Flett at Kennack Cove, to discuss sundry points on which we were not agreed, but do not remember that we used then the word beerbachite; and have since seen a little of the neighbourhood in 1909 and 1912.

half an inch in length, are " dead white ", like those in the gabbro, and often occur in scattered " coveys ". Occasionally they are joined, and include a small crystal of diallage, so they become difficult to distinguish from the smaller gabbro fragments. In fact, it looks as if the " brown-speckled " rock had occasionally partly melted down bits of the gabbro, destroying the augite rather than the felspar, and had softened and drawn out other patches, so that " a process analogous to what Professor Sollas has described in the Carlingford granites has happened here ". Dykes of a compact " greenstone " cut both these rocks, but are neither abundant nor thick; seldom, I think, more than 4 or 5 feet.[1] All along the coast to north of Porthoustock we find (1) gabbro (the dominant rock), (2) next to it the " brown-speckled ", then (3) the greenstone, much less abundant. So there is no justification for colouring all this part greenstone, as in the Survey Map. But I think the beerbachite at the Lizard must occur in rather thicker masses than it seems to do in Germany. Under the microscope my best slices of beerbachite (I have about seven in all) contain a rather strongly pleochroic hornblende, pale to rich brown, in hypidiomorphic grains, and of rather stumpy form, together with a granular augite more irregular in outline. The felspar (labradorite), also granular in outline, is in good preservation, and so is the iron-oxide, which occurs in rather small but irregular, rather numerous grains. I cannot certainly identify hypersthene or ægirine. Occasionally the felspar of the beerbachite becomes rather elongated, and the hornblende less granular close to a junction with the gabbro. One slice distinctly shows the partial melting together of the two rocks. Though it does not appear to have any marked chemical difference from several other " greenstones "[2] it seems to be so persistent in its structure and to exhibit such mineral peculiarities, that we must, I think, add beerbachite to the crystalline rocks of the Lizard, as has been already done by Dr. Flett in *The Geology of the Lizard and Meneage* (1912), where it is described briefly on p. 110 and a figure given at p. 101.

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[1] These, as a rule, are not welded to the gabbro, beerbachite, or serpentine, as the troktolite is to the last-named, so I regard the beerbachite as the forerunner of the "greenstone" (basaltic) dykes so common on the eastern coast of the Lizard.

[2] See the analysis quoted in Rosenbusch's *Gesteinslehre* and Flett & Hill's *Geology of the Lizard*, etc.

Notes on the Fauna of the Lower Devonian Beds of Torquay.

By F. R. Cowper Reed, Sc.D., F.G.S.

(*Concluded from p. 306.*)

Homalonotus (*Burmeisterella*) *Champernownei* Woodward.

1881. *Homalonotus Champernownei* Woodward, Geol. Mag., pp. 489, 528, Pl. XIII.
1882. *Homalonotus Champernownei* Woodward, ibid., p. 157, Pl. IV, fig. 3.
1918. *Homalonotus* (*Burmeisterella*) *Champernownei* Reed, Geol. Mag., pp. 315, 325.

The diagnosis of this species given by Dr. Woodward in 1881 may be summarized as follows: Body with little or no signs of trilobation. Glabella oblong, with three pairs of lateral spines and three median spines, the anterior one apparently double. No evidence of cheek-spines. Eyes nearer genal border than in *H. armatus*, and rostrum more prominently developed. Thorax composed of thirteen segments with broadly expanded pleuræ; each axial ring with pair of widely separated spines. Pygidium imperfectly known. Total length of type-specimen 8 inches; breadth (measured along curve of thorax at widest part) 3¾ inches. Spines on thorax about 1 inch apart.

The pygidium from the same locality, which Woodward described and figured in 1882 (op. cit. supra) as probably belonging to this species, possesses about twelve rings on the narrow axis and a smooth terminal piece; the anterior rings are ornamented with a double row of spines. The lateral lobes show about six pleuræ, which die out near the margin, and a smooth, slightly elevated border is present. The extremity of the pygidium is produced into a blunt spine or mucro. But the specimen is poor and considerably broken and distorted, as the original figure shows.

There are two specimens in the Torquay Museum, labelled "33/6 Lincombe Slates, Lincombe Drive", which, judging from the matrix in which they are preserved and their state of preservation, come from the same horizon, and of which the larger one at any rate may be referred to the same species as Woodward's above-mentioned pygidium. It is in good condition, though it only shows the right side and axis, but the end of the pygidium is broken off. The general shape is triangular, and it is pointed behind, the mucro being stout and cylindrical, but of uncertain length. The axis, which measures about 30 mm. in width at the front end, is elongated conical, convex, and well-defined by axial furrows; it consists of an annulated anterior portion, about 42 mm. long, composed of eleven rings (of which the last three are not separated at the sides) and of a non-annulated smooth posterior part beyond the base of the seventh pair of lateral pleuræ, which is imperfect and only 10 mm. in length, but seems to have measured about 20 mm. There is a pair of small tubercles or spines on the first axial ring, and also on the third, fourth, fifth, and sixth, and possibly on the seventh, but not on the other rings. The articulating half ring at the front end of the axis is marked off by a strong furrow, which is continued on to the lateral lobe, so as to separate off a large triangular articulating surface from the first pleura. The pleural lobe, which is perfect, shows seven pleuræ, but the seventh one is very small. The pleuræ are broad, low, and flattened, and the first one carries a large low tubercle at about half its length (or rather more), while the fourth pleura has a similar tubercle at about one-third its length, thus resembling *H. bifurcatus*. The other pleuræ are smooth. There is a smooth border of regular width round the pygidium, for the interpleural furrows do not reach the margin. The other smaller specimen has the same general characters, but seems somewhat more elongated, and there are no tubercles visible on the pleuræ or axis, but this may be due to immaturity or to individual variation, if we consider that Clarke[1] has made out his case for a similar variation in the allied tuberculated species, *H. Herscheli* Murch.

An imperfect glabella from New Cut, in the Sedgwick Museum (S. 8), measuring about 20 mm. in length, shows the lateral tubercles and the anterior median one, but the posterior part of the glabella is missing, and nothing of importance can be added to Woodward's description. There is, however, an interesting thoracic ring (S. 4) from the same locality and in the same collection which retains one of the pair of spines on the axis in an unbroken condition—a most unusual circumstance. The width of the axis in this specimen is 38 mm., according to the dimensions of the one perfect side, and the distance between the spines at their base is 22 mm. The complete spine rises up suddenly from the surface, and is directed obliquely outwards; it is straight, cylindrical, and slender, tapering regularly to a sharp point, and its length is 18 mm.

Another thoracic ring (S. 4*a*), with the axial spines 32 mm. apart, from the same locality and in the same collection, shows clearly the broad, flat articulating band on the front edge, nearly as broad in the middle as the ring itself, but near the axial furrow or constriction decreasing slightly in width. The strong, sharply impressed groove which marks it off from the ring is continued on to the pleura on each side so as to become the pleural furrow. The outer portion and tip of one pleura (S. 7) from the left side of the thorax shows this so-called pleural furrow well. This pleura has a flattened and rather rapidly broadened subspatulate extremity, with the anterior edge

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[1] Clarke, *Foss. Dev. Parana* (Mon. Serv. Geol. Miner. Brasil), vol. i, p. 93, pl. iii, figs. 1–4.

of the pleura straight or slightly concave, and the "pleural" furrow, which is nearer to it than to the posterior edge, is subparallel and dies out some distance before reaching the subtruncate rounded tip. The posterior edge of the pleura is strongly arched backwards, making a convex curve, and at the posterior outer angle of the tip bears a small but distinct marginal tubercle, which seems to be unique.

The relations of *H. Champernownei* to *H. armatus* Burm. were briefly discussed by Woodward in 1881. We may here especially draw attention to the close resemblance of the pygidium in the Torquay Museum to one of those figured by Koch,[1] under the name *armatus*, but the number and position of the spines on the axis of *H. Champernownei* are distinctive features. Woodward also commented on its resemblance to *H. elongatus* Salter, and this is specially worthy of note, though only the pygidium of the latter is known with certainty. But, as I have pointed out in my paper on the classification of the genus,[2] we cannot strictly refer it to the same group as *H. Herscheli*, though Woodward regarded the latter as one of the two nearest allied species.

Horizon.—"Red Homalonotus Beds" ("Lincombe and Warberry Grits" = Staddon Grits).[3]

Locality.—New Cut (= Lincombe Drive), Torquay. (S. 8, 11(?), 13 (?), 4 (?), 7 (?); T. $\frac{33}{6}$.)

Homalonotus (*Burmeisterella*) *elongatus*, Salter.

1865. *Homalonotus* (*Burmeisteria*) *elongatus* Salter, Mon. Brit. Trilob., p. 122, pl. x, figs. 1, 2.
1918. *Homalonotus* (*Burmeisterella*) *elongatus* Reed, GEOL. MAG., pp. 314, 325.

The pygidium on which this species was founded was sufficiently described by Salter (op. cit.).

The species has been chosen by the present author as the type of his new subgenus *Burmeisterella* (op. cit. supra), and its affinities have been discussed. It is unfortunate that no further examples of the species have been recognized, and that we are ignorant of the thorax and head-shield, though apparently Salter believed that the fragments figured by Phillips[4] belonged to it. But this conclusion seems to me to be extremely doubtful after a careful examination of the actual specimens in the Jermyn Street Museum. ($\frac{29}{2}$ M.P.G.) ($\frac{29}{3}$ M.P.G.)

Locality.—Meadfoot, Torquay.

Horizon.—Meadfoot Beds.

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[1] Koch, op. cit., t. i, figs. 3, 3*a*.

[2] Reed, GEOL. MAG., 1918, pp. 314, 324, 325.

[3] Ussher, Mem. Geol. Surv., Explan. Sheet 350, 1903, p. 35.

[4] Phillips, Palæoz. Foss. Cornw. Devon, 1841, p. 130, pl. lvii, figs. 253*a–e* (*H. Knighti* (?), figs. 253*a–c*; *H. Herscheli* (?), fig. 253*d*).

Homalonotus (*Burmeisterella*) *armatus* (Burmeister) ?

1843. *Homalonotus armatus* Burmeister, Organ. Trilob., p. 102, pl. iv, fig. 1.
1883. *Homalonotus armatus* Koch, Abh. Geol. Spec. Kart. Preuss., iv, 2, pp. 12–17, t. i, figs. 1–6.
1909. *Homalonotus* (*Burmeisteria*) *armatus* Gürich, Leitfossilien, Lief. ii, Devon, p. 156, t. xlviii, fig. 2.

It is doubtful if this species really occurs in England, but the material from Meadfoot is too poor to decide the question. Fragmentary thoracic rings and portions of the pygidium from the tough brownish sandstone of Meadfoot which are preserved in the Sedgwick Museum (S. 5) appear to possess the characters described and figured by Koch (op. cit.). They seem certainly distinct from *H. Champernownei* of the red argillaceous beds of the New Cut.

Horizon.—Meadfoot Beds (sandstone).

Locality.—Meadfoot, Torquay (S. 5).

Homalonotus (*Burmeisterella*) sp.

There is in the Sedgwick Museum one left free cheek, somewhat distorted, from the New Cut, Torquay, which has the peculiarity of the border being raised and sharply bevelled so as to form an angulated edge. In this respect it agrees with the cheek figured by Drevermann[1] as *Homalonotus* sp. from the Lower Coblenzian of Oberstadtfeld, and in describing it this author remarks that the possession of this border separates it from all other species of the genus. In our specimen, which is complete except for the posterior margin, the general surface of the cheek is swollen and elevated near the eye but sinks down into a broad concentric submarginal concavity which rises to the sharply angular inner edge of the border; the latter increases in width to the genal angle, and has a bevelled outer face. There is the base of a large, stout, rounded spine or tubercle near the inner edge of the swollen portion of the cheek, as in Drevermann's figure. A more quadrate, less perfect free cheek from the same locality at Torquay is also preserved in the Sedgwick Museum, and resembles the other figure (fig. 1) given by Drevermann of this undetermined species. The presence of the spine-base on the cheek suggests that it belongs to the subgenus *Burmeisterella*, and probably one of the species above described should receive it.

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, Torquay (S. 9, 100).

Homalonotus (*Parahomalonotus*) *Whidbornei* sp. nov. (Pl. IV, Fig. 4.)

Definition.—General shape elongated, flattened; trilobation nearly obsolete. Head-shield short, broadly subtriangular, truncated in front in middle (with a small median epistomal point projecting below ?). Epistomal sutures on upper surface of head-shield

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[1] Drevermann, *Palæontographica*, xlix, 1902, p. 74, t. ix, figs. 1, 2, 3 (?).

parallel and in continuation of anterior branches of facial sutures, cutting front margin at right angles and bounding on each side broad flattened band forming a prora equal in width to pre-glabellar area, from which it is cut off by a gently concave transverse suture. Middle-shield broadly subtriangular, truncated in front by transverse suture, with subrectangular anterior lateral angles projecting forwards, and situated apart about one and a half times the front width of the glabella. Facial sutures with anterior branches curving in strongly from the eyes and then running straight forwards parallel to each other to pass into epistomal sutures in the same line; posterior branches bending suddenly outwards behind eyes parallel to posterior edge of head-shield. Glabella scarcely elevated, subrhomboidal, wide at base, but narrowing at about half its length to a truncate anterior end, about two-thirds the length of the head-shield and one-third its width at base. Axial furrows shallow. Pre-glabellar area gently concave, about one-fourth the length of the glabella. Occipital ring well marked, gently rounded, with meso-occipital portion wider in middle than pleuro-occipital portions. Occipital furrow strong, arched slightly forwards at base of glabella. Eyes small, slightly elevated, situated at about half the width of the glabella from its side and at about half its length. Fixed cheeks flattened, but rising to slight convexity at eyes. Free cheeks slightly convex in region of eyes (marginal portion unknown).

Thorax much flattened, with lateral portions almost horizontally extended, composed of thirteen segments; axis very wide, only marked off from pleural lobes by slight constriction of segments and by faint depression on surface. Pleuræ subcylindrical, flattened (ends not preserved), with narrow submedian pleural furrow well marked.

Pygidium semicircular? Axis very broad at front end, conical, rapidly tapering behind, composed of eight to nine complete rings. Lateral lobes not well preserved.

Dimensions (34–6 T.) :—

		mm.
Length of head-shield		28
Length of glabella		17
Distance from anterior end of glabella to front margin of head-shield (= pre-glabellar area + prora)	c.	7
Width of glabella at base	c.	22
Width of glabella at front end	c.	14
Distance of eye from posterior margin of head-shield	c.	8
Distance of eye from side of glabella . . .	c.	7
Length of thorax		40
Length of axis of pygidium		17
Width of axis at front end	c.	19

Horizon.—Meadfoot Beds.

Locality.—Field at back of Kilmorie, near Hope's Nose, Torquay ($\frac{34}{6}$ T).

Remarks.—The single specimen of this trilobite is in the Torquay Museum (Tablet 34–6); it is not in a good state of preservation, and it is difficult to make out the characters of the front of the head-shield, the left-hand side of which is missing as well as the greater part of the free cheek and lateral margin of the right side. The ends of the thoracic pleuræ are also broken off, and the lateral lobes of the pygidium are not preserved. The whole specimen has also been flattened out by pressure, but it seems that it naturally possessed an almost complete absence of transverse convexity, and that the trilobation was indistinct or nearly obsolete. The affinities of the species seem to lie with that group of species of the subgenus *Parahomalonotus*[1] which comprises *H. lævicauda* Quenst.,[2] *H. planus* Sandb., and *H. obtusus* Sandb., as defined by Koch (op. cit.). The pygidium from the "Hauptquartzit" figured by Kayser[3] as *H. multicostatus* Koch, appears to bear a close resemblance to our specimen.

Dalmanites (*Asteropyge*) *laciniatus* (Roemer).

1844. *Cryphœus laciniatus* F. Roemer, Rhein. Uebergangsgeb., p. 82, t. ii, fig. 8.
1889. *Cryphœus laciniatus* Kayser, Abh. k. preuss, geol. Landesanst., N.F., Heft i, p. 88, t. xxiv, figs. 1–8 (? 9, 10).

In the Sedgwick Museum there is the impression of the left half and posterior end of a somewhat distorted pygidium (S. 1) from the Red Beds of the New Cut, Torquay, which precisely agrees with Kayser's definition and figures of the common form of "*Cryphœus*" *laciniatus* Roem., from Daleiden. The five lateral spines and the much broader, but shorter, flattened, sublanceolate median posterior spine are well seen, though the first lateral spine is almost entirely broken off in our specimen. Another smaller example in the same collection and from the same locality has lost the first two spines on the left side, but shows the whole posterior part of the pygidium, including the lateral lobe and last spine of the right side. The characters of the axis and pleuræ agree with Kayser's definition. There is also one fairly well preserved head-shield (S. 2) in the Sedgwick Museum, likewise from New Cut, showing the eyes, glabella, and part of the right cheek, and another left free cheek (somewhat crushed), with the genal spine attached. The number of rows of lenses in the eye in this specimen is about 27, and none of the rows appear to consist of more than eight lenses. These fragments of the head-shield do not differ from Kayser's description of the common form of the species, but much confusion has arisen from the different applications of the specific name *laciniatus*, so that it is necessary to limit the synonymy which is frequently given. Probably the trilobite from Torquay, which Salter[4] termed *Phacops* (*Cryphœus*) *punctatus* (Stein.), should be referred to this species, but on the other hand the specimens from Liskeard which he figured

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[1] Reed, GEOL. MAG., 1918, p. 326.
[2] Koch, op. cit., p. 55, t. viii, figs. 1–7.
[3] Kayser, Abhandl. geol. preuss. Landesanst., N.F., i, 1889, p. 80, t. xi, fig. 2.
[4] Salter, Mon. Brit. Trilob., 1864, p. 59.

under this name seem to belong to Kayser's species *Lethææ*.[1] The form from North Devon which Whidborne[2] described as *Dalmanites* (*Cryphæus*) *laciniatus* var. *occidentalis* is quite distinct from our Torquay specimens. The use of the subgeneric name *Asteropyge* in place of *Cryphæus* is here adopted.[3]

Dimensions.—Pygidium (S. 1): length, (I) *c.* 17 mm., (II) *c.* 9 mm.; width (I) *c.* 20 mm., (II) *c.* 11 mm. *Head-shield* (S. 2): length, 8 mm.; width, *c.* 18 mm.

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, Torquay (S. 1, 2).

Beyrichia (*Zygobeyrichia*) *devonica* (Jones & Woodward).

1889. *Beyrichia devonica* Jones & Woodward, Geol. Mag., p. 386, Pl. IX, Figs. 3*a*–3*d* (? 4, 5).

1916. *Zygobeyrichia devonica* Ulrich, Prof. Paper 89, U.S. Geol. Surv., p. 291, pl. xxvii, figs. 1–6.

The species *Beyrichia devonica*, which was first described by Jones and Woodward from the New Cut, Torquay, has been recently recorded from the Chapman Sandstone (Lower Devonian) of Maine by Ulrich (op. cit.), who selects it as the type of a new genus, which he calls *Zygobeyrichia*, characterized "by the partial or complete obsolescence of the posterior lobe and by the excessive development of the ventral junction of the median and anterior lobes". It may be questioned whether this should not denote subgeneric rather than generic rank. The type-specimens of the species are in the Sedgwick Museum.

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, Torquay. (S. 89.)

EXPLANATION OF PLATE IV.

Fig. 1.—*Homalonotus* (*Burmeisterella*) *bifurcatus* sp. nov. Head-shield. × 1½. Staddon Grits: New Cut, Lincombe Drive, Torquay. (Sedgwick Museum.)

Fig. 2.—Ditto Pygidium of same specimen. × 1½. (Sedgwick Museum.)

Fig. 3.—Ditto. Impression of same pygidium, showing terminal spines. × 1½. (Sedgwick Museum.)

Fig. 4.—*Homalonotus* (*Parahomalonotus*) *Whidbornei* sp. nov. Nat. size. Meadfoot Beds: field at back of Kilmorie, near Hope's Nose, Torquay. (Torquay Museum.)

On the Geology of Castle-an-Dinas Wolfram Mine.

By E. H. Davison, B.Sc.

THERE are two hills named Castle-an-Dinas in West Cornwall, one near Penzance and the one on which the Wolfram Mine is situated, which lies about 2 miles east of St. Columb Major and about 4 miles to the north of the St. Austell granite mass.

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[1] Kayser, op. cit., p. 86, t. xi, figs. 5, 6.

[2] Whidborne, Quart. Journ. Geol. Soc., vol. lviii, 1897, p. 445, pl. xxxiii, figs. 9–13.

[3] Reed, Geol. Mag., 1905, pp. 173, 225.

The hill rises 700 feet above sea-level, and forms a conspicuous feature in the landscape; it is surmounted by an ancient earthwork which has given the hill its name. In 1915 the outcrop of a lode was traced on the northern slope of the hill, and this has been developed by mining operations and yields a remarkably clean wolfram ore.

GEOLOGICAL STRUCTURE OF THE DISTRICT.

In a paper read before the Royal Geological Society of Cornwall[1] the writer described the general geology of the district, but since then the development of the mine has been carried further and fresh light has been thrown on the geological structure of Castle-an-Dinas hill.

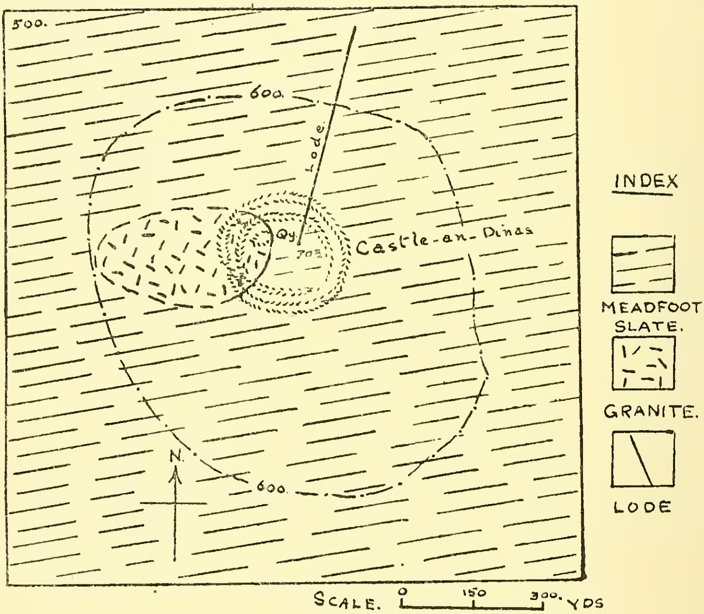

FIG. 1.—Sketch-map of Castle-an-Dinas.

The hill is mainly built of Meadfoot Slates, which strike approximately east and west, and are folded on axes roughly parallel to the strike. The hill lies within the metamorphic aureole of the granite, and the slates have in addition been subjected to intense pneumatolytic alteration, as a result of which the contact minerals have been almost completely destroyed; in one case, however, the slates were seen to contain wollastonite.

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[1] "The Geology of Castle-an-Dinas and Belowda Beacon": Proc. R.G.S. Corn., vol. xix.

The result of the pneumatolytic alteration is a rock consisting essentially of quartz and tourmaline with some white mica and iron oxide, in which the cleavage, slip-cleavage, and folding of the original slate have been preserved. Under the microscope the slate is seen to be composed of layers of tourmaline needles, alternating with layers of clear quartz, the tourmaline layers containing mica and iron oxide. The slate maintains this character close up to the lode walls, though specimens collected from the neighbourhood of the lode fissure were seen to contain fine grains of cassiterite.

On the summit of the hill the slate is penetrated by a granitic rock, which, as exposed on the hill-top, has the appearance of a granite-porphyry. On tracing the outcrop to the west, down the hill-side, it has a more normal granitic character, but nowhere is it a coarsely crystalline granite such as occurs on Belowda Beacon to the east. The granite outcrop and that exposed in the mine workings seem to be in the nature of apophyses of the Belowda mass to the east.

On the south of the hill a quartz-porphyry dyke traverses the slate with a strike almost east and west, and a south underlie. The rock is highly tourmalinized, and has been worked for its tin contents.

THE CASTLE-AN-DINAS LODE.

The lode outcrops on the north side of the hill with a strike of 15° E. of N. It is a practically vertical fissure in the slate, and is at present being worked by two adits driven into the hillside at an interval of about 10 fathoms. The width of the lode varies from a few inches to about 3 feet, but an average width of about 2 feet is maintained with fair regularity.

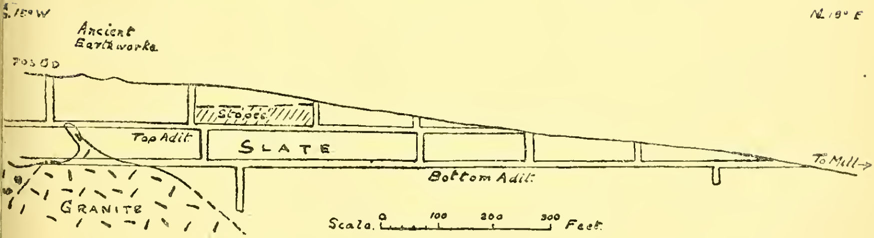

FIG. 2.—Section of workings, Castle-an-Dinas Mine. From plan lent by Mr. J. Chenoweth.

The lode-filling consists of white vein quartz with irregularly distributed patches and strips of very coarsely crystallized wolfram, the patches having a diameter of a few inches up to 2 feet or so. A remarkable character of the lode-filling is the almost complete absence of minerals other than quartz and wolfram. Occasional copper stains are seen and there is a little native copper but only in insignificant amounts. There is almost complete absence of tin, the ore concentrates containing less than 0·3 per cent. The country rock, on the other hand, is seen under the microscope to contain cassiterite, and samples taken from the slate in the neighbourhood of the granite have been assayed and found to contain as much as 1 per cent. These values are, however, too inconsistent to have any economic importance. Another remarkable character is the absence of tourmaline in the lode material, while the country rock is highly tourmalinized.

Towards the far end of the upper level the eastern wall is formed of a granitic rock much decomposed, forming white or pink clay enclosing partly decomposed felspar fragments, quartz, flakes of white mica, and needles of tourmaline. There are also harder bands of greisen composed of quartz, pale brown mica, which contains lithia and is very strongly birefringent, and topaz, with grains and needles of tourmaline.

In the lower level at the point indicated in the section (Fig. 2) granite appeared in the floor of the lode in the form of a soft clay, containing grains of quartz and flakes of muscovite. This rose slowly towards the south, and passed into a hard fine-grained granite, which extended above the roof of the level. On driving a cross-cut west, the base of the granite was seen in the floor where it was underlain by clay-slate, and on continuing the level to the south the slate again appeared above the granite, the surface of the latter continuing with undulations. A winze has been sunk 120 yards north of the point where the granite first appears, but though driven to a depth of 87 feet no granite was met with. These facts point to the granite having an irregular tongue-like form rather than to its being a portion of the main mass.

Development is not sufficiently advanced to show if the lode continues down into the granite, but there are irregular patches of quartz with wolfram in the granite tongues, and it seems probable that the lode fissure was only deflected by the presence of the harder rock. It does not, however, follow that the lode-filling maintains the same character.

The intimate way in which the granite penetrated the clay-slate can be seen in specimens of clay-slate collected from points in the levels where no granite is in sight; these are seen to be traversed by fine veins of granitic material which cut across the foliation and vary from an inch or so to less than one-sixteenth of an inch in width. Under the microscope these fine veins are seen to consist of clear quartz, pale brown, highly birefringent mica and tourmaline, with occasional grains of cassiterite.

The Castle-an-Dinas lode is almost unique in character when compared with other lodes of West Cornwall. It is characterized by the following points:—

1. The absence of pneumatolytic minerals such as tourmaline, fluorspar, and topaz from the lode contents.

2. The absence of sulphides and the very small proportion of cassiterite present.
3. The remarkably coarse texture of the lode-filling.

The veins of the Kit Hill Mine, Callington, are in some respects similar in character, but they differ in containing cassiterite, tourmaline, and mispickel; they also occur just below the surface of the granite and not in the clay-slate. There is also some similarity in the veins of the Hemerdon Hill stockwork, which are like those of Kit Hill, with a much smaller proportion of mispickel in the veins, which also contain scorodite. There is again a similar veinstone in the middle lode of the recently reopened Killifreth Mine, St. Day, in which coarse patches of wolfram occur in clear quartz, which is also traversed by veins carrying cassiterite, blende, and mispickel.

The Castle-an-Dinas lode seems to represent the results of mineral deposition in the upper part of the tin and tungsten zone, the sequence of events having been somewhat as follows:—

1. Folding and cleaving of the clay-slate.
2. Intrusion of granite followed by pneumatolytic action, which resulted in the tourmalinization of the slate and the formation of greisen, kaolinized granite, and deposition of cassiterite in the slate.
3. The opening of the lode fissure.
4. Filling of the fissure by means of hot solutions or pegmatite-like intrusions.

On Jurassic Ammonites from East Africa, collected by Prof. J. W. Gregory

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

(*Concluded from p. 320.*)

Genus Sowerbyceras Parona & Bonarelli.

Sowerbyceras aff. *tortisulcato* d'Orbigny sp. (Pl. I, Figs. 5*a–c*.)

1870. *Phylloceras* n.sp. aff. *tortisulcato* (d'Orbigny) Neumayr, "Jurastud. III, Die Phylloc. Dogger Malm," p. 345, pl. xvii, fig. 9.
1895. *Ph. subtortisulcatum* (Pompeckj ?) Parona, Nuove osservaz. s. l. fauna e l'età degli strati con *Posidonomya alpina* nei Sette Communi Pal. Ital., vol. i, p. 10.
1897. *Ph.* sp. aff. *tortisulcatum* (d'Orbigny), Hochstetter, "Die Klippe St. Veit bei Wien," Jahrb. kk. R.A., vol. xlvii, pt. i, p. 142.
1897. *Sowerbyceras Neumayri* Parona & Bonarelli, "Sur la Faune Callov. Infér. Savoie": Mém. Acad. Sc. Savoie, ser. 4, vol. vi, p. 120.

Dimensions.—Diameter . . 15 mm.
Height of the last whorl . . 53 per cent of the diameter.
Thickness . . 46 ,, ,, ,,
Umbilicus . . 18 ,, ,, ,, .

Description.—This specimen is characterized by a subrectangular whorl-section with depressed venter, which is peculiar to Fontannes's group of "*Phylloceras*" *tortisulcatum.* The greatest thickness of the whorls is near the umbilical margin, but the sides are almost parallel and the ventral area is evenly convex, not flattened. The ratio of height to thickness is about 7 : 6, as compared with 4 : 3 in *Sowerbyceras tortisulcatum,* according to Pompeckj,[1] and with 8 : 7 at most in *S. protortisulcatum* Pompeckj sp. The umbilicus is comparatively large and deep; its walls are rounded and not abrupt. There are about four constrictions to the whorl, beginning as conspicuous grooves with a forward bend at the umbilicus, but becoming less distinct on the lateral area. After bending back again they become once more pronounced, passing across the periphery with a sinus that is concave forwards.

The suture-line consists of very distinctly diphyllic external, first and second lateral saddles, and of monophyllic auxiliary saddles. This type of suture-line is well illustrated in de Loriol's [2] figure of that of *S. tortisulcatum* d'Orbigny sp.[3] (which he calls a species of the *Renggeri* Marls), and in that of *S. helios* Noetling,[4] though here the saddles, perhaps, are drawn so as to appear too plump. There are seven auxiliary lobes and saddles, but the inner of these are merely denticulations, though present already at a diameter of 9 mm. This number agrees with that of the auxiliary lobes in the three Callovian species, *S. antecedens* (Pompeckj),[5] *S. transiens* (Pompeckj),[6] and *S. subtortisulcatum* (Pompeckj).[7] The internal portion of the suture-line consists of six saddles, and it is important to note the monophyllic character of the first lateral saddle (dorsal), which shows the specimen described here to belong to the "Formenreihe" of *Phylloceras tortisulcatum* = *Sowerbyceras,* and not to the group of *Ph. ultramontanum,* as the backward bend of the constrictions of the ventral area would suggest. The internal portion of the suture-line shown in Fig. 5*c* is not drawn from the same part of the specimen as the external half.

Observations.—Pompeckj,[8] when establishing the "Formenreihe" of *Phylloceras tortisulcatum,* stated that the developmental tendencies in this series were as follows: (*a*) increase in the size of the umbilicus from the geologically older to the younger forms; (*b*) change of whorl-section from elliptical to quadrangular, with the greatest thickness of the whorl moving nearer and nearer to the umbilicus; (*c*) increase in the angularity of the constrictions, with a tendency to bend forward a second time on the periphery; (*d*) decrease in the complication of the lobe-line. On account of this last character Pompeckj called the series retrogressive, and he also mentioned that

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[1] Loc. cit., Revision, 1893, p. 54.

[2] Loc. cit., 1893, text-fig. 1, p. 5.

[3] d'Orbigny's figure (*Ter. Jurass.*, pl. 189, fig. 3) is probably inaccurate.

[4] *Der Jura am Hermon,* Stuttgart, 1887 pl. ii, fig. 3*c*.

[5] Loc. cit., Revision, 1893, p. 47.

[6] Ibid., p. 51.

[7] Ibid., p. 52.

[8] Loc. cit., Revision, 1893, pp. 40–5.

the monophyllic ending of the first lateral saddle of the dorsal suture was characteristic of this group. On examination of the present specimen it is found that these points do not allow of its immediate placing in the series, for, whereas constrictions and umbilicus point to an early form, whorl-shape and suture-line ally the specimen more with the later species of the series. To judge by specimens of *S. tortisulcatum,* however,[1] the secondary forward convexity of the constrictions (on the periphery) becomes more pronounced only in larger examples, and in young specimens there is only the angular bend on the lateral area, whereas the ventral portions of the sulci are straight. Also the section of the inner whorls is much thicker near the umbilical edge and narrower at the venter than it is in the adult whorls. After attaining a diameter of about 7 mm. the proportions given in Fig. 5*b* appear, and the section gradually changes to the quadrangular shape characteristic of the adult *S. tortisulcatum,* with very square ventral area.

Although, therefore, in the adult *S. tortisulcatum* the proportions are different, the inner whorls are comparable to the specimen collected by Professor Gregory, but the constrictions of d'Orbigny's species show a ventral convexity already at a diameter of 9 mm. The course of the constrictions also separates the East African specimen from *S. protortisulcatum* Pompeckj sp., found by the writer in profusion in the Argovian of Jebel Zaghuan, Tunisia.[2] The whorl-section here is very similar, and the suture-line also agrees very well in general characters, but has a far smaller number of elements. In *S.* cf. *Loryi* Munier-Chalmas sp.,[3] recorded from the same locality, the smaller umbilicus exactly agrees with the specimen under review, but according to Pervinquière [4] the typical specimens of this *acanthicus*-zone ammonite show constrictions only on the body-chamber. This author (after Kilian) also united with *S. Loryi* the ammonite described by Gemmellaro [5] as *Phylloceras silenus* Dumortier & Fontannes. The Sicilian form agrees with the specimen here described in dimensions (Gemmellaro, for a specimen of the diameter of 21 mm., gives the percentages as 51, 44, and 15) and, to a certain extent, in the suture-line, for in a much larger specimen there are only four monophyllic auxiliary saddles, as in the suture-line of *S. protortisulcatum,* given by the writer.[6] A number of forms of *Sowerbyceras* more or less agree with the East African specimen in dimensions and suture-line, but have a different (forward) course of the constrictions, e.g. *S. Tietzei*

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[1] Some of the specimens examined belong to the Astier Collection, preserved in the British Museum (Nat. Hist.), and d'Orbigny stated that he had received limonitic specimens of *A. tortisulcatus* from M. Astier (*Ter. Crét.*, p. 164).

[2] Loc. cit., 1913, p. 565.

[3] Ibid., p. 566.

[4] *Études de Pal. Tunis.*, i, Ceph. Ter. Second, 1907, p. 16.

[5] Loc. cit., 1877, p. 185, pl. xvi, fig. 1–3

[6] Loc. cit., 1913, pl. liii, fig. 2*c*.

Till,[1] *S. ovale* Pompeckj sp.,[2] and others. On the other hand, in the oldest specimen of *Sowerbyceras* figured, the Bathonian *S. Neumayri*, the constrictions are typically angular, and the thinness of that specimen only characterizes it as distinct.

The type of constrictions shown by the specimen here described is found in the group of *Phylloceras ultramontanum* Zittel, and is well illustrated in e.g. *Phylloceras mediterraneum* (Neumayr) in Favre,[3] *Ph. zignodianum* (d'Orbigny) in Vacek,[4] and in *Ph. Frederici-augusti* Pompeckj,[5] but according to the latter author in this group the first lateral saddle of the internal (dorsal) suture is diphyllic.[6] Also, though the suture-line of d'Orbigny's *A. zignodianus* shows bifid saddles, not unlike those of a *Sowerbyceras*, the quadrate whorl-section of the East African specimen and the absence of the lateral lappet at the angle of the constrictions are against a closer comparison with any of the forms of the group of *Ph. ultramontanum.*

It is probable that the specimen is most nearly related to the older forms of *Sowerbyceras* recorded by Neumayr, Parona, and Hochstetter. The former author mentioned (apart from the specimen from the Bathonian of Mount Crussol, near Valence, Ardèche, referred to above) a fragment from the Klaus beds of Buscecs, Transylvania,[7] as the oldest specimen which can be referred to d'Orbigny's species. Hochstetter recorded from the Klaus beds of St. Veit, near Vienna, very small *Phylloceras*,[8] the curious course of the constrictions of which favoured the assumption that they belong to Pompeckj's "Formenreihe" of *Ph. tortisulcatum.* Parona recorded his specimen (doubtfully referred to *Ph. subtortisulcatum* Pompeckj[9]), together with *Lytoceras adeloides* and other forms of the Upper Bajocian and Bathonian, from the *Posidonomya alpina* beds of the Southern Alps.

Horizon and Distribution.—The group of *Phylloceras tortisulcatum* (d'Orbigny) ranges from the Bathonian up to the Tithonian, but

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[1] Op. cit., 1910, p. 260, pl. xvi (I), figs. 12–14.

[2] Op. cit., 1893, p. 48, pl. i, figs. 4 and 5. This species is not included in the genus *Sowerbyceras* by Parona & Bonarelli.

[3] "Descr. Foss. Ter. Jurass. Mont. Voirons (Savoie)": Mém. Soc. Pal. Suisse, vol ii, 1875, p. 19, pl. i, fig. 10. In this Argovian form the constrictions are for too deep.

[4] Op. cit., 1886, pl. v, fig. 14 only, *non* pl. iv, figs. 8–10.

[5] Op. cit., 1893, pl. i, fig. 12–14.

[6] It may be mentioned that Quenstedt (*Amm. Schwäb. Jura,* p. 762, pl. lxxxvi, and p. 864, pl. xciii) had included in *A. tortisulcatus* both forms put by Pompeckj into the "Formenreihe" of *Phylloceras ultramontanum,* also typical *Sowerbyceras.* The writer is not inclined to lay too much stress on the course of the constrictions shown to be variable in many other *Phylloceras.* On the other hand, *Sowerbyceras* is probably a descendant of the Bajocian *ultramontanus* group, as Parona & Bonarelli (loc. cit., p. 117) suggested.

[7] Loc. cit., 1870, p. 345.

[8] Loc. cit., 1897, p. 142.

[9] De Loriol (loc. cit., 1900, p. 18) was doubtful about the justification of the separation of *Ph. subtortisulcatum* Pompeckj from the typical *Ph. tortisulcatum* d'Orbigny sp.

according to Kilian [1] does not persist into the *Boissieri* beds of the lowest Neocomian. The type itself is Callovian and of wide distribution, both in the Alpine-Mediterranean region, as far as the Caucasus, but (with related forms) also in Wurtemberg.

Locality.—No. 10, from the grey, otherwise unfossiliferous limestone, beside the break-pressure tank, mile $\frac{1}{1}\frac{1}{1}$ on the Mombasa Pipe-line (together with *Phylloceras* cf. *disputabile* Zittel).

Genus PROTETRAGONITES Hyatt.

Hyatt [2] created this genus for *Lytoceras quadrisulcatum* d'Orbigny sp., a form that is very abundant in the Lower Valanginian,[3] though similar ammonites occur in the Tithonian.[4] Vacek [5] traced the group of *L. quadrisulcatum* back to his Bajocian *L. rasile*, and included [6] in the same group *L. rubescens* Dumortier sp. and *L.* n.sp. ind.,[7] which forms are assigned to the genus *Megalytoceras* S. Buckman by its author.[8] Vacek remarked that the Tithonian *Lytoceras municipale* Oppel sp. was so near to *L. rasile* that in spite of the enormous chronological separation one might almost be inclined to consider them specifically identical. The writer is not convinced that the Tithonian–Neocomian *quadrisulcatus* group (= *Protetragonites* s.str.) can be traced back even to the Bathonian *L. tripartitum* Raspail sp., and, in fact, considers the latter to require a new generic name since its suture-line alone clearly distinguishes it from the other Lytocerata. Owing, however, to lack of material and consequent inability either to prove the independence of this group with the necessary precision, or to trace its relations to such forms as *L. rasile* Tornquist *non* Vacek,[9] *L. tripartitiforme* Gemmellaro, etc., the specimen to be described here is provisionally referred to the genus *Protetragonites*.

Protetragonites cf. *tripartitus* Raspail sp. (Pl. I, Figs. 6*a*–*c*.)

1829. *Amm. tripartitus* Raspail, Ann. Sci. Obs. (Lycé, 1831), pl. xi, fig. 5, pl. xii, fig. 7.
1841. *A. quadrisulcatus* d'Orbigny, Ter. Crét., p. 151, pl. xlix, fig. 3.
1842. *A. tripartitus* (Raspail), d'Orbigny, Ter. Jurass, p. 496, pl. 197, figs. 1–4.
1846. *A. polystoma* Quenstedt, Cephalopoden, pl. xx, fig. 8.
1860. *A. tripartitus* (Raspail), Ooster, Cat. Ceph. foss., p. 66, pl. xvii, figs. 1–3.

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[1] *Lethæa geognostica*, ii, Mesozoicum, vol. iii, Kreide, pt. i, Unterkreide, fasc. 2, 1910, p. 171.

[2] In Zittel's *Text-book of Palæontology*, edited by C. R. Eastman, vol. i, pt. ii, 1900, p. 569.

[3] See e.g. Kilian, *Lethæa geognostica*, ii, Mesozoicum, vol. iii, Kreide, pt. i, fasc. 2, 1910, p. 174.

[4] Ibid., p. 171, and Sayn ("Amm. Pyrit. Marnes Valang, S.E. France": Mém. Soc. Géol. France, Pal., No. 23, 1901, p. 2) identifies his Valanginian specimens with Zittel's Tithonian ammonites.

[5] Loc. cit., 1886, p. 64.

[6] Ibid., p. 60.

[7] Ibid., p. 64, pl. i, figs. 6, 7.

[8] "On certain Genera and Species of Lytoceratidæ": Q.J.G.S., vol. lxi, 1905, p. 151.

[9] Loc. cit., 1898, p. 28 (160), pl. v, fig. 8.

1866. *A. tripartitus* (Raspail), Benecke, "Üb. Trias u. Jura i. d. Süd-Alpen"; Geogn. Pal. Beitr., p. 175.
1891. *Lytoceras tripartitum* (Raspail), Haug, "Les Chaînes subalp. entre Gap et Digne": Bull. Serv. Carte Géol. France, vol. iii, p. 79.
1897. ,, ,, ,, Hochstetter, "Die Klippe v. St. Veit, b. Wien": Jb. k.k. R.A., vol. xlvii, Hft. i, p. 143.
1905. ,, ,, ,, Simionescu, "Üb. Alt. Klaus-Schichten Süd. Karpathen": Verh. k.k. R.A., No. 10, p. 212.

Description.—This fragment, consisting of two cameræ only, is about 7 mm. in length. There is very little difference in the dimensions of the two terminal (septal) surfaces, so that the coiling must have been extremely slow. The thickness of the whorl is nearly equal to the height, which latter is 4·5 mm. The section, however, is not circular, but compressed, and the dorsal furrow is very shallow, indicating contact with (but not inclusion of) the inner whorls. The fragment, fortunately, shows a constriction, with a forward bend on the side and a backward sinus on the periphery.

The suture-line consists of very few elements, namely, a very long but narrow external (ventral) lobe, a bifid external saddle, about the size of the (equally bifid) lateral lobe, and slightly larger than the (also bifid and similar) lateral saddle.[1] The second lateral lobe is shorter than the first lateral lobe (which, itself, is shorter than the external lobe), and after the very simple and almost entire second lateral saddle there only is a very small auxiliary lobe, followed by a broad and more or less entire umbilical saddle. In describing the almost identical suture-line of *A. tripartitus* (Raspail) d'Orbigny[2] apparently had regarded this auxiliary lobe as merely an indentation in the second lateral saddle ("auxiliary saddle" in d'Orbigny), but the continuation of the suture-line on the dorsal side shows it to be a true third lobe. The deep internal lobe is flanked by two long and monophyllic saddles. The "cross"[3] characteristic of the group of *Lytoceras fimbriatum* (in a wider sense, not only *Fimbrilytoceras* S. Buckman) is not very pronounced. The septa are rather distant (there are only three in the space of 7 mm.), and they do not interpenetrate.

Observations.—The fragment differs in section from the type-figure, and especially from the compressed examples, such as that figured by Quenstedt as *A. polystoma*, by having the thickness nearly equal to the height of the whorl. This probably is not due only to the small size of the present specimen, nor to the fact that the typical specimens of *P. tripartitus* are generally (elliptically) compressed. In examples of this species from the Bathonian of the South

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[1] In fig. 6*c* the first lateral saddle is drawn just a shade too slender. On account of the smallness of these specimens collodiotypes could not be taken.
[2] Loc. cit., Ter. Jurass., 1842, p. 497.
[3] See Pompeckj, loc. cit., Revision, 1893, text-fig. 24 on p. 115.

of France [1] at a whorl height of 3·75 mm. the thickness amounts to 3·25 mm. and the ratio increases to 8·75 : 6·25 mm. Further, in the typical specimens the constrictions begin with a more decided forward bend from the umbilicus. On the other hand, there is almost perfect agreement in the suture-line, both external and internal; so that even if the East African specimen cannot be identified with *P. tripartitus*, it, at any rate, must belong to a closely related form.

Lytoceras tripartitiforme Gemmellaro,[2] which also occurs associated with *Phylloceras Kudernatschi* Hauer sp., *Ph. disputabile* Zittel, and other forms of the Klaus Beds, is distinguished from the specimen here considered by the different course of the constrictions. This difference also separates the East African example from *L. polyhelictum* (Boeckh), a form of the *Parkinsoni* zone of Hungary and Daghestan, and considered to be near to *P. tripartitus* by Neumayr et Uhlig.[3] The whorl-section of *L. polyhelictum* is more like that of the present specimen than is the compressed shape of *P. tripartitus*; on the other hand, the three saddles shown in the suture-line of the Daghestan form, given by the latter authors, are different from those shown in Fig. 6*c*.

Lytoceras polyanchomenum Gemmellaro,[4] from the *macrocephalus* beds of Sicily but recorded also from the Swiss Oxfordian,[5] may agree with the specimen here examined in whorl-section and possibly in the constrictions,[6] but the suture-line of the East African specimen certainly does not show the lateral branch of the dorsal lobe continued on to the lateral area.

Horizon and Distribution.—*P. tripartitus* is a very common ammonite in the zones of *Oppelia fusca* and *Zigzagiceras zigzag* (Bathonian) in the South of France,[7] and also occurs in the Bathonian of Italy, Switzerland, Austria, and the Carpathians. Hochstetter [8] records the species even from the Lower Bajocian, but his specimens were badly preserved, and on the following page of the work quoted he calls *P. tripartitus*, "of the Bathonian, a younger form of the group of *Lytoceras quadrisulcatum*." He recorded [9] sixty-five specimens from the Bathonian of St. Veit, and added that Griesbach already had called this species "abundant and easily identifiable,

[1] There were no specimens available for comparison, but the writer was immediately supplied (through the kindness of M. Stuer, of Paris) with three prototypes of Raspail's from Aix (see Haug, loc. cit., 1908, p. 1022) and four specimens from Chaudon, Basses-Alpes (ibid., p. 1023).

[2] Loc. cit., 1877, p. 135, pl. xix, fig. 9.

[3] Loc. cit., 1892, p. 39, pl. iii, fig. 2*a–d*.

[4] Loc. cit., 1872, p. 14, pl. iv, figs. 2, 3.

[5] Favre, "Descr. Foss. Terr. Oxf. Alp. Frib.": Mém. Soc. Pal. Suisse, vol. iii, 1876, p. 35.

[6] According to Gemmellaro's description, not the figures cited. Pl. iii, fig 3, in Favre (loc. cit.) is very near, being the young.

[7] Haug, loc. cit., 1908, pp. 1019–53.

[8] Loc. cit., 1897, p. 109.

[9] Ibid., p. 143.

common also in the Bathonien Inférieur of France". Kilian,[1] however, mentions the species from the Bajocian again and states that Lory had found it with *A. lunula*. It seems possible that *P. tripartitus* or a mutation of that form may go up into the Callovian, but the records of the higher horizons are by older authors, e.g. Quenstedt,[2] Pictet,[3] and Studer,[4] and no mention is made of *P. tripartitus* in the many modern descriptions of Callovian faunæ, in which, on the other hand, *Lytoceras adeloides* is almost universally present. At any rate, Raspail's species is so abundant in the Bathonian of the South of France, that Repelin [5] even speaks of a "zone of *Lytoceras tripartitum*".

Locality.—No. 550, Mwachi River, Pipe-line Crossing, about $\frac{30}{0}$. (Together with *Phylloceras* cf. *Kunthi* Neumayr and *Hecticoceras* sp. juv.)

Genus HECTICOCERAS Bonarelli.

The specimen described here is an undoubted Oppelid, but its reference to the genus *Hecticoceras* is somewhat doubtful. Its association with Ammonites that are comparable with Bathonian species suggests affinity with those Bathonian Oppelids that have been put into *Hecticoceras* by e.g. Haug, Popovici-Hatzeg, and Parona. These forms, on the one hand, seem to be allied to some of the normal evolute "*Œcotraustes*" of the *Parkinsoni* and *fusca* zones, but not to the early *Œcotraustes*, such as that figured by Vacek,[6] which has a different suture-line. On the other hand, they probably develop into such more or less involute forms of the *macrocephalus* beds as *Oppelia pleurocyma* Parona & Bonarelli,[7] or as *Oppelia subdisca* d'Orbigny sp.[8] These forms have been confused with the earlier and similar *Oppelia* of the *fusca* type, and with *Oxycerites*, groups that are involute and already have a highly specialized suture-line in the Bathonian. To separate, however, the development here indicated from the later and similar

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[1] *Montagne de Lure*, Paris (Masson), 1889, p. 79.

[2] *A. polystoma* Quenstedt is recorded from a "black limestone of *macrocephalus* age" from Barrême.

[3] This author (*Traité de Pal.*, vol. ii, 1854, p. 698) stated that *A. tripartitus* was characteristic of the Callovian in France, and was found in Germany, together with *A. Murchisonæ*.

[4] In *Geologie d. Schweiz*, 1853, vol ii, p. 45, *A. tripartitus* is recorded as occurring, with *Phylloceras zignodianum* and *Macrocephalites*, in the Callovian, but on p. 52 it is associated with *S. tortisulcatum*, *Ph. tatricum*, and also *A. plicatilis*, and put into the Oxfordian.

[5] "Jurass. Chaîne Nerthe et l'Étoile": Bull. Soc. Géol. France, ser. III, vol. xxvi, 1898, p. 520. *Ph. mediterraneum* and *Oppelia* here occur with *P. tripartitus*.

[6] Loc. cit., 1886, pl. ix, fig. 13. S. Buckman ("Certain Jurassic Species of Amm. and Brach.": Q.J.G.S., vol. lxvi, 1910, p. 96) is inclined to put this as low as the *discites* zone.

[7] Loc. cit., 1897, p. 129, pl. iii, fig. 1.

[8] Loc. cit., Ter. Jurass., p. 421, pl. 146, and Favre, "Contrib. à l'Étude des *Oppelia*": Mem. Soc. Pal. Suisse, vol. xxxviii, 1912, p. 31.

Lunuloceras[1] would be open to objections from etymological reasons, for *A. hecticus* itself would then be a *Lunuloceras.* In any case the definite relations of the many forms referred to the genus *Hecticoceras* remain yet to be worked out, also the connexion with *Oppelinæ* below and the *Ochetoceras–Trimarginites* fauna above.

Hecticoceras sp. juv. (Pl. I, Fig. 7*a–c*.)

Compare :—

1905. *Hecticoceras Haugi*, Popovici-Hatzeg, "Les Céph. Jurass. M. Strunga": Mém. Soc. Géol. France, Pal., No. 35, p. 18, pl. iv, fig. 3, pl. v, figs. 2–10.

Dimensions.—		
	Diameter . .	8·3 mm.
	Height of the last whorl . .	40 per cent of the diameter.
	Thickness . .	32 ,, ,, ,,
	Umbilicus . .	30 ,, ,, ,,

Description.—This specimen represents only the inner whorls of a larger ammonite since it is septate throughout. The periphery shows a keel only on the last two-thirds of the outer whorl, and the earlier portion of the shell is perfectly smooth, with flat sides and a rounded venter. The open umbilicus has steep but rounded walls. The ornament which is shown near the end of the shell (in the form of about six costæ) is distinct near the periphery only; and only one or two of these obscure folds seem to be very indistinctly continued, with a lateral forward bend, on the sides, though they do not reach the umbilical border. There is an indication near the end of the specimen of a differentiation of the periphery into lateral zones (on each side of the keel) marked off from the sides by an edge, whereas on the previous portion of the last whorl the ventral area is rounded and gradually passes into the sides.

The suture-line consists of a deeply forked, trifid principal lobe, much deeper than the external and second lateral lobes, of irregularly bifid external first and second lateral saddles, and of three auxiliary lobes, slightly raised towards the umbilicus.

Observations.—The suture-line of this specimen is very similar to that of a young *Lunuloceras*, and agrees in all essentials with that of "*Harpoceras*" *lunula* (Zieten) given by Noetling,[2] or with the suture-lines of a number of specimens of this almost universal species-group from many different localities. On the other hand, the suture-line of young Oppelids from the *zigzag* hemera of Powerstock Station, Dorset, is also very similar to that of the specimen here described, as is that given for *Oppelia subradiata* (Sowerby) var A. by Favre.[3] With a very immature specimen it is a matter of opinion whether it should be considered as allied to the Bathonian

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[1] Tsytovitch ("Le genre *Hecticoceras*": Mém. Soc. Pal. Suisse, vol. xxxvii, 1911) has again drawn attention to the difficulty of separating *Hecticoceras* and *Lunuloceras* on purely morphological grounds.

[2] *Der Jura am Hermon*, 1887, p. 18, text-fig. 3.

[3] Loc. cit., 1912, fig. 1 on p. 13.

Hecticoceras[1] rather than to other contemporaneous Oppelids. It should be pointed out, however, that the East African specimen might equally well represent the inner whorls of such Callovian *Lunuloceras* as those figured by Quenstedt,[2] Waagen,[3] Till,[4] Tsytovitch, etc., or even of such Oxfordian and Argovian forms as those figured by de Loriol[5] and Noetling.[6] As has been pointed out before, its affinity with the Bathonian forms of the type of "*Oppelia*" *bisculpta* Oppel sp. = *A. Henrici* Kudernatsch *non* d'Orbigny[7] is suggested only by the associated ammonites.

Hecticoceras Haugi, Popovici-Hatzeg, has a narrower umbilicus in the adult, and the whorl-section, then, also differs considerably,[8] but the young probably comes very near to the specimen here examined. On the other hand, the suture-line appears to be more complex in the Roumanian specimens.

Horizon.—Hecticoceras, comparable to the East African specimen, occur in the Bathonian as well as the Callovian.

Locality.—No. 550, Mwachi River, Pipe-line Crossing. Found together with *Protetragonites* cf. *tripartitus* Raspail sp. and with *Phylloceras* cf. *Kunthi* Neumayr.

CONCLUSIONS.

The fauna described in the present paper consists, then, of the following seven Ammonites :—

Phylloceras aff. *Kudernatschi* Hauer.
,, sp. ind.
,, cf. *Kunthi* Neumayr.
,, cf. *disputabile* Zittel.
Sowerbyceras sp. aff. *tortisulcato* d'Orbigny sp.
Protetragonites cf. *tripartitus* Raspail sp.
Hecticoceras sp. juv.

It is a matter for regret that more definite identifications could not be given, but not one of the specimens represents an adult shell, and three of them are fragmentary. It is one of the latter (*Protetragonites* cf. *tripartitus*) that has been mainly relied on in determining the fauna as probably of Bathonian age ; but this species already occurs in the *Parkinsoni* beds of the uppermost

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[1] As represented by e.g. "*Oppelia*" *retrocostata* Grossouvre ("Études sur l'Étage Bathonien" : Bull. Soc. Géol. France, ser. III, vol. xvi, 1888, p. 374, pl. iii, figs. 8, 9), and the Cornbrash species "*Harpoceras*" (*Ludwigia*) *subpunctatum* (Schlippe, "Fauna Bath. Oberrhein. Tiefl." : Abh. Geol. Spec. K. Els.-Lothr. vol. iv, 1888, No. 4, p. 196, pl. v, fig. 3). Haug (loc. cit., 1898, p. 82) considers them identical.

[2] *Amm. Schwäb. Jura*, 1887, pl. lxxxii, e.g. figs. 23 and 32.

[3] Loc. cit., 1873, e.g. pl. xiii.

[4] Loc. cit., 1910, e.g., pl. xviii (iii).

[5] Loc. cit., 1898, e.g. *H. Bonarellii*, de Loriol, pl. iii, figs. 19–21, and 1900, pl. iii, p. 14.

[6] Loc. cit., e.g. "*Harpoceras*" *Guthei*, Noetling, p. 20, pl. ii, figs. 6–8*a*.

[7] Loc. cit., 1852, pl. ii, figs. 9–13.

[8] Loc. cit., 1905, text-fig. 9 on p. 19

Bajocian. On the other hand, it is probable that its record from the *macrocephalus* or even later beds (by several authors) was based on the occurrence of similar forms, which are, as yet, undescribed.

Phylloceras aff. *Kudernatschi* and *Ph.* cf. *disputabile* confirm the Bathonian age, though the latter species has been called "indifferent",[1] and like *Phylloceras mediterraneum* Neumayr, probably includes a variety of more or less closely related forms of its group. Both *Ph. Kudernatschi* and *Ph. disputabile* have been recorded from younger beds, but also from the Bajocian. *Phylloceras Kunthi* has been found in the lower Bathonian, but is a species belonging to the zone of *Macrocephalites macrocephalus*. In India and the Caucasus ammonites, even from the *athleta* beds, have been referred to this species.

The genera *Sowerbyceras* and *Hecticoceras* already occur in the Bathonian, but are typically Callovian and range into higher beds. Arranged according to their localities, *Ph.* cf. *disputabile* and *Sowerbyceras* sp. aff. *tortisulcato* have been found together in the "grey, otherwise unfossiliferous limestone", and *Phylloceras* aff. *Kunthi*, *Protetragonites* cf. *tripartitum*, and *Hecticoceras* sp. juv. were also collected in one bed at the Pipe-line Crossing, Mwachi River. *Ph.* cf. *Kudernatschi* is recorded from a different locality, and *Phylloceras* sp. ind. also was found by itself, west of the Mwachi River. The specimens, therefore, that might suggest a post-Bathonian age, namely *Sowerbyceras* and *Hecticoceras*, occur in each of the two former localities associated with ammonites referred to Bathonian forms, and a Bathonian age thus seems most appropriate to the fauna.

As regards distribution (apart from the European occurrences mentioned under the specific descriptions, and the doubtful record of *Phylloceras* cf. *Kunthi* from India), *Phylloceras disputabile* has been found in India and East Africa, but the ammonites referred to this species probably are not specifically identical with the specimen here recorded. None of the other *Phylloceras* and *Lytoceras* described from the Jurassic of Kutch belong to the types represented in Professor Gregory's collection. From Madagascar also (the "Callovian" beds of which Dacqué considers to be the equivalent of his *macrocephalus* zone of Pendambili) only *Phylloceras mediterraneum*,[2] or a local variant, has been recorded. The latter, together with *Phylloceras Feddeni* Waagen and *Macrocephalites* also occurs in the Iron Oolite of Tanga in East Africa, but the fauna described in the present paper differs from all these in having the group of *Phylloceras heterophyllum* represented, and probably by no less than three different forms.

The lower Bathonian, with a more or less neritic facies, is well developed in the whole of East Africa, but apparently only

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[1] Till, op. cit., 1910, i, p. 185.

[2] Also recorded by Suess (*Das Antlitz der Erde*) from Zanzibar.

indeterminable Cephalopod remains so far have been recorded from its rocks. It is interesting to note that six out of seven specimens described in the present paper belong to the long-lived and stable genera *Phylloceras* and *Lytoceras*, giving the fauna a typically Mediterranean aspect. The influx of this Mediterranean fauna must have occurred along the geosynclinal extension of the Tethys, which has been called the " Channel of Mozambique ". This geosynclinal, before the Bathonian transgression, apparently had not attained the edge of the present African continent. A *Sonninia* and a *Parkinsonia*, but no *Phylloceras* or *Lytoceras* have been found in the Bajocian of Madagascar, but no pre-Bathonian ammonites occur on the African continent west of this geosynclinal.

Hecticoceras is found in North-West Europe and in the boreal Callovian as well as in Alpine-Mediterranean deposits. On the other hand, *Phylloceras* and *Lytoceras* have been found in Alaska, though there also they are claimed to be confined to a geosynclinal extension of the Mid-Pacific (which latter enabled the exchange of the Spiti and Andine faunas). Professor Haug's conception of *Phylloceras* and *Lytoceras* as stenothermal genera, frequent only in the deepest parts of the geosynclinal areas, does not explain all the facts of their distribution. In a previous paper the writer favoured the view that like other thin-shelled organisms, but unlike many other Ammonites and Nautiloids, *Phylloceras* and *Lytoceras* may have been pelagic swimmers, and thus in their distribution show a certain dependence on the currents of the Jurassic seas.

EXPLANATION OF PLATE V.

FIG. 1.—*Phylloceras* aff. *Kudernatschi* (Hauer). Mombasa Pipe-line, at mile $\frac{12}{5}$. (× about 1·1.) 1*a*, lateral aspect; 1*b*, sectional outline; 1*c*, suture-line (× about 3).

FIG. 2.—*Phylloceras* sp. ind. West of Mwachi River, about $\frac{17}{0}$. Nat. size. 2*a*, lateral view; 2*b*, outline-section; 2*c*, portion of suture-line (× about 3).

FIG. 3.—*Phylloceras* cf. *Kunthi* Neumayr. Mwachi River, Pipe-line Crossing. Nat. size. 3*a*, lateral aspect; 3*b*, peripheral view; 3*c*, suture-line (× about 5).

FIG. 4.—*Phylloceras* cf. *disputabile* Zittel. Mombasa Pipe-line, mile $\frac{11}{11}$. 4*a*, lateral aspect (× about 1·1); 4*b*, opposite side, showing constrictions, with restored outline of complete shell, nat. size; 4*c*, outline-section of whorl, magnified × 2; 4*d*, suture-line (portion) × about 6.

FIG. 5.—*Sowerbyceras* aff. *tortisulcato* d'Orbigny sp. Same locality as last. 5*a*, lateral aspect (× about 1·1); 5*b*, outline-section, magnified × 2. 5*c*, suture-line, composite and not drawn from one septal edge.

FIG. 6.—*Protetragonites* cf. *tripartitus* (Raspail). Mwachi River, Pipe-line Crossing, about $\frac{30}{0}$. 6*a*, lateral aspect, magnified × 2; 6*b*, section (× 2); 6*c*, suture-line, external and internal (× about 7·5).

FIG. 7.—*Hecticoceras* sp. juv. Same locality as last. 7*a*, lateral aspect (× 2); 7*b*, peripheral view (× 2); 7*c*, suture-line (× about 9).

On the Investigation of the Mechanical Constitution of Loose Arenaceous Sediments by the method of Elutriation, with special reference to the Thanet Beds of the Southern Side of the London Basin.

By Herbert Arthur Baker, M.Sc., F.G.S.

(*Continued from p. 332.*)

GRAPHICAL EXPRESSION OF MECHANICAL ANALYSES.

In giving graphical expression to the data obtained by mechanical analyses of sediments, the use of curves was found to be very satisfactory. After some consideration the method finally adopted was to mark off along a horizontal abscissa a scale of percentage-weights, from 0 to 100, and upwards, along a vertical ordinate, a scale of grade-size limits from 0 to ·2 mm. and beyond. In cases where the range of the diameters of the grains in a sample is very great it would be necessary to employ a method of reducing the representative lengths, and this has sometimes been done by marking off lengths proportional to the logarithms of the diameters; but in the case of the arenaceous sediments dealt with by the writer, the necessity for this did not arise, and in the curves illustrating this paper, the ordinate lengths shown are directly proportional to the diameters represented. The length along an abscissa, intercepted between the first ordinate and the curve, represents the *total* percentage weight of the sample which, up to the limit of size specified, has been washed off, and the remaining length signifies the percentage-weight yet remaining to be dealt with. A tendency towards verticality on the part of the curve denotes relative absence or paucity of material of the sizes specified, and, correspondingly, a tendency towards horizontality signifies a preponderance of material of the size specified. Hence, a fine-grained sediment will give a curve occupying the lower part of the diagram, and with increasing coarseness of sediment the curve climbs successively higher and higher. (See Figs. 2, 3, and 6.)

TREATMENT OF DATA YIELDED BY MECHANICAL ANALYSES.

(1) *Failure of the "Purdy Fineness Factor".*

A method whereby the mechanical constitution of a sediment can be expressed by means of a representative number has been much sought after, but up to the present no really satisfactory result has been achieved. Such a number, could it be obtained, would undoubtedly be of great utility. It could be plotted upon maps, and ideas connecting the mechanical constitution of a sediment with its geographical distribution could be gained. The need for such a number in connexion with the economic aspect of the mechanical composition of sands and clays is much felt. In America an attempt has been made to obtain a "fineness factor" which shall be proportional to the total surface-area of the sample.

The assumption is made that the surface-areas of two powders, derived from a unit volume, are in inverse ratio to the average diameter of their grains, and the reciprocal of the average diameter is taken as the factor. The assumption is now known to be erroneous, but as the factor affords a convenient approximation it is often used. This factor was proposed by Jackson, and amended by Purdy, and goes under the name of the "Purdy fineness factor". It was first propounded to meet the requirements of the ceramic industry, but it has been admitted that since the difference between the true surface-factor and that calculated from the average diameter increases as the diameter decreases, more confidence may be placed in the Purdy factor as calculated for sediments coarser than the fine material used in the ceramic industry. The method of obtaining the Purdy fineness factor will be clear from the following:—

Suppose the sample to have been separated by elutriation into four grades, thus:—

Grade.	Diameters ranging from	Average Diameter.	Surface Factor.	Percentage-weight present.
1	a to b mm.	$\frac{a+b}{2}$ mm.	$\frac{2}{a+b}$	A
2	b to c ,,	$\frac{b+c}{2}$,,	$\frac{2}{b+c}$	B
3	c to d ,,	$\frac{c+d}{2}$,,	$\frac{2}{c+d}$	C
4	d to e ,,	$\frac{d+e}{2}$,,	$\frac{2}{d+e}$	D

Then the Purdy fineness factor = total surface factor =

$$\left(\frac{2}{a+b}\times\frac{A}{100}\right)+\left(\frac{2}{b+c}\times\frac{B}{100}\right)+\left(\frac{2}{c+d}\times\frac{C}{100}\right)+\left(\frac{2}{d+e}\times\frac{D}{100}\right)$$

The total surface-factor is obtained by multiplying the surface-factor of each grade by the percentage-weight of that grade, and finding the sum of the products thus obtained.

Before proceeding to test the utility of the Purdy fineness factor in relation to arenaceous sediments, it is legitimate first to make the criticism that the true average diameter of the grains in any separated grade is likely to be seriously different from the half-sum of the limiting sizes.

Bearing in mind that the Purdy fineness factor should show larger numbers for finer sediments, the above formula was applied to the results of a large number of mechanical analyses carried out on arenaceous sediments by the writer. The result was to show the complete failure of this factor to serve any useful purpose as a means of comparing arenaceous sediments from the point of view of fineness or coarseness of grain. The following selected pair of sediments will suffice to illustrate this point:—

	CLAY.	SILT.		SAND.			
	mm. <·01	mm. >·01 <·05	mm. >·05 <·1	mm. >·1 <·125	mm. >·125 <·15	mm. >·15 <·2	mm. >·2
Sample *A* .	3·72	1·58	8·48	29·86	50·26	4·22	1·88
Sample *B* .	0·78	11·54	52·68	29·62	4·90	0·48	—

Both samples are of the Thanet Sand from Messrs. Tuff & Hoar's Pit, East Wickham, but whereas sample *A* is from the extreme top of the deposit, sample *B* is from about the middle of the deposit. The mechanical analysis reveals at once that sample *A* is a distinctly coarser sediment than sample *B*. In the case of sample *A*, over 50 per cent of the material is sand between the limits of ·125 and ·15 mm., whereas in the case of sample *B* over 50 per cent is of the coarse silt grade. When the elutriation curves of the two sediments are plotted this distinction is very clearly shown. (See Fig. 2.) The calculation of the Purdy fineness factor should therefore produce the larger number in the case of sample *B*. But this is not the case, viz.:—

Sample *A*. Purdy factor =

$$\left(\frac{1}{\cdot 005}\times\cdot 0372\right)+\left(\frac{1}{\cdot 03}\times\cdot 0158\right)+\left(\frac{1}{\cdot 075}\times\cdot 0848\right)+\left(\frac{1}{\cdot 1125}\times\cdot 2986\right)$$

$$=\frac{\cdot 0372}{\cdot 005}+\frac{\cdot 0158}{\cdot 03}+\frac{\cdot 0848}{\cdot 075}+\frac{\cdot 2986}{\cdot 1125}$$

$$=7\cdot 44+\cdot 53+1\cdot 13+2\cdot 65$$

$$+\left(\frac{1}{\cdot 1375}\times\cdot 5026\right)+\left(\frac{1}{\cdot 175}\times\cdot 0422\right)$$

$$+\frac{\cdot 5026}{\cdot 1375}+\frac{\cdot 0422}{\cdot 175}$$

$$+3\cdot 65+\cdot 24$$

$$=15\cdot 64.$$

In the case of sample *B* the figures are:—

Purdy factor =

$$\frac{\cdot 0078}{\cdot 005}+\frac{\cdot 1154}{\cdot 03}+\frac{\cdot 5268}{\cdot 075}+\frac{\cdot 2962}{\cdot 1125}+\frac{\cdot 0490}{\cdot 1375}+\frac{\cdot 0048}{\cdot 175}$$

$$=1\cdot 56+3\cdot 85+7\cdot 02+2\cdot 63+\cdot 35+\cdot 02$$

$$=15\cdot 43$$

Hence we see that the very insignificant difference obtained is on the wrong side.

It becomes necessary, therefore, to seek another basis of comparison for the fineness or coarseness of grain of arenaceous sediments.

From the mathematical point of view the question presents great difficulties. It does not appear to be possible to apply any simple mathematical process to the data afforded by elutriation, which does not deprive them of their uniqueness. Moreover, the application of the ordinary processes of mathematics to the elutriation-curve of a sediment would only give some result or results based upon a series of mathematical curves agreeing more or less approximately with portions of the actual curve. The latter being available, the present writer is of opinion that it is better to obtain some result or results from actual treatment of the graph itself.

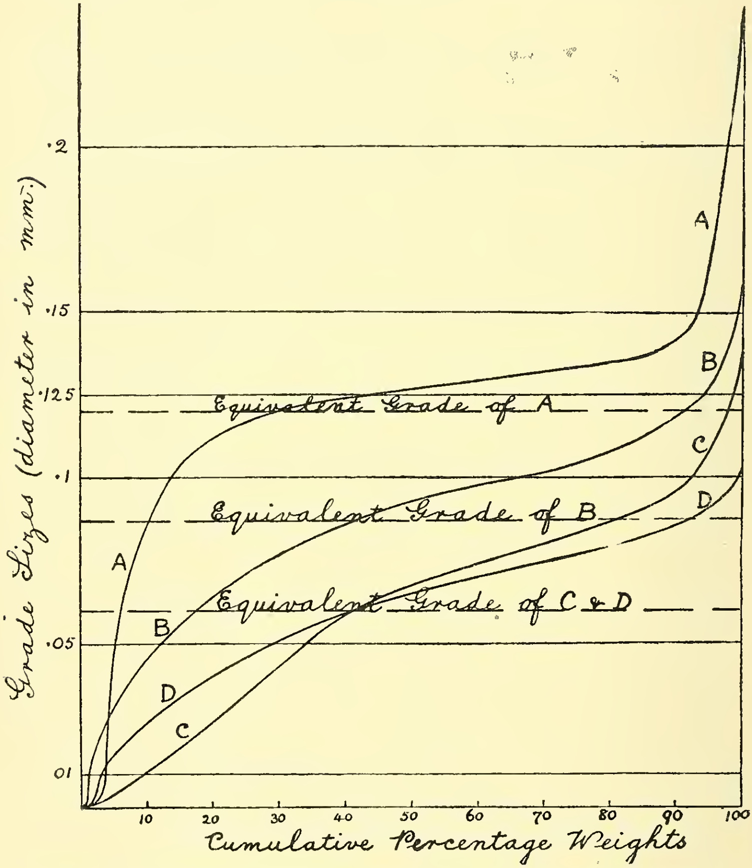

Fig. 2.—Elutriation curves of sediments (reduced) to show meaning of "Equivalent Grade".

In the search for a characteristic number to represent the mechanical constitution of a sediment, the actual average diameter of the grains in a sample, besides being exceedingly difficult, if not impossible to obtain, is useless, since it gives a result quite out of keeping with the sizes of the grains in the bulk of the sample. This arises from the fact that the clay grade in the sample, however insignificant its percentage-weight may be, contains such an enormous amount of tiny particles that the average diameter is reduced to a figure of an order quite different from that sought. Consequently a method is required which affords a result influenced by the percentage-weights of the various grades present.

(2) *The "Equivalent Grade" of a Sediment.*

The plotting of the elutriation-curve of a sediment from the data yielded by the mechanical analysis of it, affords a means of obtaining graphically, the value of the definite integral of diameter of particles with respect to percentage-weight. The value of this integral is represented by the area under the curve enclosed between the first and last ordinates and the first abscissa or base-line of the diagram. It may readily be determined, with considerable accuracy, by the use of the planimeter. The result is small or large, according as the sediment under consideration is fine or coarse, since the coarser the sediment the higher its curve climbs and the greater the area enclosed beneath it. If we suppose the case of an ideal sediment in which the grading is perfect (i.e. the sediment consists entirely of grains of some one specified diameter), the elutriation-curve would be a horizontal straight line (an abscissa), parallel to the first abscissa and passing through the point on the first ordinate representing the specified diameter. Let us suppose, for argument, that all the grains in this ideal sediment are of diameter 0·2 mm. Then the area under the curve is a rectangle whose area is a product of the length representing 0·2 mm. and that representing 100 per cent weight. The figure sought as the representative average of the diameters of the particles (taking into account percentage-weights of grades) is obtained by dividing the area under the curve by the length of the base-line representing 100 per cent weight, and interpreting the length so obtained in terms of the scale of lengths employed to represent diameters. Now, perfectly graded sediments of this kind do not appear to occur in nature, but there is no reason why we should not extend the argument, by analogy, to apply to actual sediments. Consider an imperfectly graded natural sediment. It gives a certain known value for the integral of diameter of particles with respect to percentage-weight. Suppose it were possible to substitute for this sediment a perfectly graded material giving an equivalent value for the area under the curve. What would be the diameter of the particles in this ideal sediment? The answer is supplied by finding the mean ordinate of the area under the curve, which is done by finding the area under the curve by means of the planimeter and dividing the result by the length representing 100 per cent weight. The length so obtained is then interpreted in terms of the scale of lengths employed to represent diameters. The value of this mean ordinate may then very well be taken as the representative diameter, for comparative purposes, of the particles in the sediment. The figure obtained may be termed the "Equivalent Grade" for the particular sediment.

Fine sediments will give a low figure for the "Equivalent Grade" and the figure will increase with increasing coarseness of sediment.

On applying this method to the two sediments considered above, when referring to the Purdy factor, we find that sample *A* (the coarser sediment) gives an Equivalent Grade of ·120 mm., whereas the finer sample *B* gives ·087 mm. As the result of applying the method to the data obtained by carrying out a very large number of mechanical analyses of arenaceous sediments, the writer now concludes that we have, in this "Equivalent Grade", a valuable means of comparing sediments from the point of view of their coarseness or fineness of grain, and one superior to any method at present in vogue.

(3) *The "Grading Factor" of a Sediment.*

It cannot be said, however, that the Equivalent Grade supplies a figure which is unique for each and every sediment. The elutriation curve of a sediment is unique—each and every sediment gives its own particular curve—and only two mechanically identical sediments would yield identical curves. It is possible, however, for two different curves to yield the same Equivalent Grade figure. Hence it is necessary for a further factor to be obtained, based upon the respective proportionalities of the grades present in the sediment, so that this second figure, taken in conjunction with the Equivalent Grade, affords a pair of numbers which together give complete uniqueness to any sediment. The writer has devised a means whereby a second figure—a "Grading Factor"—can be obtained, so that if two sediments give the same Equivalent Grade they differ in their Grading Factor, and vice versa. Incidentally, the Equivalent Grade and the Grading Factor of a sediment are figures which should prove of the utmost utility in connexion with the economic aspect of the question of the mechanical constitution of sediments, and, further, there is every reason to suppose that as our knowledge of the conditions governing the transport, sorting, and deposition of sediments progresses, they will, in addition, prove of considerable value to the geologist.

The Grading Factor of a sediment is found as follows: Curve *C* in Fig. 2 represents the elutriation-curve of a sediment (Lower Thanet Beds, Charlton Pit), which gave the following mechanical analysis :—

CLAY.	SILT.		SAND.	
<·01 mm.	>·01 mm. <·05 mm.	>·05 mm. <·1 mm.	>·1 mm. <·125 mm.	>·125 mm.
9·52	24·17	58·98	6·01	1·32

The Equivalent Grade of this sediment, determined from the curve, is ·059 mm., and its equivalent, perfectly graded ideal sediment is represented by the horizontal abscissa inserted on the graph in the appropriate place.

Now, the area enclosed between the first ordinate, the Equivalent Grade line, and the curve, represents the measure of the *variation* of the sediment (having regard to diameters and percentage-weights) *below* the grade of the ideal, perfectly graded equivalent sediment, and the corresponding equal area enclosed between the last ordinate, the Equivalent Grade line, and the curve, similarly represents the measure of the variation of the sediment *above* the grade of its ideal, perfectly graded equivalent. Hence, the sum of these two areas gives the measure of the *total* variation of the sediment from the hypothetical perfectly graded equivalent. If we now subtract this variation-area from the total area under the curve we get a remainder which expresses the measure of the tendency of the sediment towards constancy of grading or restriction of the diameters of the constituent grains to one specified size, namely that of the Equivalent Grade. In the case of a hypothetical perfectly graded sediment, that is, one in which there is perfect constancy of grading, or complete restriction of the grain diameters to one particular dimension, there is no variation-area, consequently the area which expresses the measure of its tendency towards grading perfection is the area under the curve.

Hence, if we consider the ratio—

$$\frac{\text{Area expressing measure of tendency towards grading perfection}}{\text{Total area under curve}}$$

we see that it assumes the value unity when the grading is perfect. The Grading Factors of naturally occurring sediments will approach nearer and nearer to the value unity as their degree of grading approaches nearer and nearer to perfection. Hence, the Grading Factor of a sediment is given by :—

$$\frac{\text{Total area under curve} - \text{Total variation area}}{\text{Total area under curve}}$$

Determining, with the aid of the planimeter, the Grading Factor of the sediment under consideration, we obtain the value ·581.

Shown on the same diagram (curve *D*) is the elutriation-curve of another sediment (Lower Thanet Beds, Tuff & Hoar's Pit, East Wickham), which gave the following mechanical analysis :—

CLAY.	SILT.		SAND.
<·01 mm.	>·01 mm. <·05 mm.	>·05 mm. <·1 mm.	>·1 mm.
2·90	26·20	70·90	—

The Equivalent Grade of this sediment is identical with that of the first, viz. ·059 mm., but the two curves are not identical. It can be seen at a glance that the first sediment shows greater variation than the second, and hence the latter yields a higher Grading Factor, the value in this case coming out at ·693. We see, then, that the Equivalent Grade of a sediment together with its Grading Factor afford a pair of values unique for any sediment.

It should be remarked that in selecting sediments to serve as illustrations of the utility of these two factors, the writer has deliberately chosen examples in which the differences in mechanical constitution are by no means great. In general, arenaceous sediments show very much greater differences in mechanical composition than are to be observed in the examples selected. If, then, comparatively insignificant differences can be indicated by the methods of treatment here outlined, how much more apparent become the greater differences very generally found.

When the data yielded by mechanical analyses of sediments have accumulated sufficiently, it should be a simple matter to draw up a scheme of classification, according to mechanical constitution, for the loose detrital sediments, based upon determined values of Equivalent Grades and Grading Factors. The determination of the values of these factors in the case of those sediments which are used in the industries can hardly fail to be of great utility. The importance of mechanical constitution in the case of glass sands and in the case of the refractory sands used for furnace and foundry purposes has already been clearly demonstrated by Professor Boswell. But from the purely geological point of view there is every reason to believe that from the detailed study of the mechanical constitution of the loose detrital sediments of the geological column, much light will be thrown upon many obscure questions, especially in reference to conditions of deposition of sediments. When palæontological evidence fails, the stratigrapher is thrown back upon the lithology of the deposits, and in the case of a loose, arenaceous sediment the lithological evidence is very strongly and helpfully augmented if the elutriation-curve be available.

(*To be continued.*)

REVIEWS.

Echinoid or Crinoid ?

Ueber einige palaeozoische Seeigelstacheln (*Timorocidaris* gen. nov. und *Bolboporites* Pander). By Johannes Wanner. Versl. Natuurk. Afdeel. Akad. Wetensch. Amsterdam, xxviii, pp. 797–813, pl. 1920.

PROFESSOR WANNER has found in the Permian of Timor some echinoderm remains which he believes to be radioles of an echinoid, and therefore names *Timorocidaris*. In shape one of these objects is like a mushroom, with rounded top and short stalk. The alleged upper outer face is normally pustulate, but sometimes smooth. The circular outline is sometimes modified by truncations, as though these supposed radioles had been crushed close together on the test, as are the radioles of *Colobocentrotus*. The large majority (2,150 out of 2,422) of these bodies have the end of the stalk bevelled off by three facets, which meet round a small central hollow. " The remarkable feature is that these three surfaces are fashioned as articular facets with a pronounced crinoid character." Each facet shows the fulcral ridge, separating an outer crescentic ligament-face from the two inner muscle-plates, which are divided by a median groove or notch. At the middle of the ligament-face, adjoining the fulcral ridge and opposite the notch, is a depression, which may indicate a more pronounced ligament-scar (as Dr. Wanner interprets it) or a canal for a nerve. Some of the remaining specimens have merely a hollow at the end of the stalk, and Dr. Wanner believes that this hollow represents one of the facets. He claims to have material proving a passage from one type of structure to the other, but his figures are not convincing. Some of the specimens have an ornament resembling that of *Cidaris scrobiculata* and one or two other radioles from the Alpine Trias.

It is possible that there are some true echinoid radioles in this material, but I am at a loss to understand how the majority with the three articular facets can be interpreted thus. Setting aside the fact that no such structure has ever been seen in the Echinoidea, is it not obvious that such facets could not have been used for the attachment of one rigid body to a single rigid surface of whatever shape ? Each of these facets must have been attached to a separate, movable, skeletal element of similar section, i.e. with a rounded outer back and grooved inner surface. That which was fixed as the stalk, that which was movable, was the group of structures attached to the facets. Those structures must have diverged from one another at the outset.

Dr. Wanner makes a number of hypotheses, each of which he tests conscientiously and finds unworkable ; he also exerts himself to smooth away certain other objections to regarding these objects as radioles; *inter alia* the total absence from his collections of any coronal plates to bear them. It never occurs to him to make the hypothesis that these objects are crinoids after all. Let us see how that works out. Each, we may suppose, has normally three radials, laterally fused into a short stalk, and springing from a solid rounded mass into the composition of which the basals (and infrabasals, if any) presumably enter. Each radial facet supported, on this hypothesis, the first brachial of an arm. As to the nature of those arms we have no evidence other than that afforded by the facet, from which we gather that they were independently movable and moderately massive. They must have included the viscera, since there is not sufficient space between the radials, and therefore were probably joined laterally by a finely plated membrane.

On this hypothesis the hemisphere from which the radial stalk springs was a sort of anchor resting on the sea-floor, perhaps sometimes embedded in sand or sometimes inserted in a crevice which checked its free growth. Some of the specimens may have been dragged along the bottom and so lost their pustules. Others may have been partly weathered and have had their facets eaten away. Individuals fixed in awkward positions may have developed one or two facets at the expense of the others. All such aberrant cases do not amount to 12 per cent. The crinoid hypothesis, then, seems open to fewer objections than the echinoid. Just as Dr. Wanner's *Timorechinus* proved to be a crinoid allied to the Poteriocrinidæ, so his *Timorocidaris* will probably turn out to be a crinoid with stem reduced to a massive anchor, as in *Agassizocrinus*, and with arms reduced to three, as in *Tribrachiocrinus*. It may be genetically connected with one or other of those late Carboniferous genera, but that is not a necessary conclusion.

Professor Wanner argues from his supposed radioles with their abnormal facets to *Bolboporites*, which likewise he interprets as an echinoid radiole with a peculiar facet. If, however, *Timorocidaris* be a crinoid, this analogy loses its force. In no other respects does Dr. Wanner throw fresh light on *Bolboporites*. Had he taken the trouble to make thin sections through his specimens and to study their stereom with the microscope, he might have substituted some useful fact for a deal of ingenious but, I fear, useless fancy.

F. A. BATHER.

THE PALÆOZOIC TILLITES OF NORTHERN NORWAY. Bidrag til Finmarkens Geologi, av OLAF HOLTEDAHL. Norges Geologiske Undersökelse, Nr. 84. Kristiania, 1918.

IN 1890 Dr. H. Reusch announced his discovery in the Varangerfjord district, E. Finmarken, of rocks of glacial origin "belonging to a much older period than the Ice Age". He referred them to the Palæozoic, and, relying upon the petrographical similarity of the beds associated with the tillites to the Sparagmite

Formation of Norway, suggested that they were of Torridonian or Lower Cambrian age. A Quaternary age was subsequently advocated by O. E. Schiötz, but Sir A. Strahan supported Dr. Reusch's interpretation. Whilst the deposits certainly belong to the Palæozoic, there was very little evidence for regarding them as Cambrian, yet this was widely accepted, and the Varangerfjord beds are commonly correlated with similar deposits of Cambrian age in China and Australia, and cited to support the hypothesis of a Cambrian ice age. As a result of detailed work in the northernmost part of Norway, Dr. O. Holtedahl places a new interpretation upon the age and significance of the tillites.

The succession in Finmarken is made out as follows :—

Sandstone Series
- *Upper* with tillites.
- *Lower* with dolomites, and, in the west, volcanic rocks.

Lower Cambrian shales with *Platysolenites antiquissimus* and *Obolus* sp.

PRE-CAMBRIAN.

The pre-Cambrian gneisses and schists occupy the southern part of the area—the later sedimentaries occurring to the north, and being themselves covered in the north-west by an overthrust metamorphic series dating from the Caledonian movements. The discovery in Spitsbergen of Downtonian sediments lying unconformably upon the eroded remnants of the Caledonian Range prove that in this region this great deformation was completed before Upper Silurian times, and therefore the tillites can be referred to some period between the Lower Cambrian and Upper Silurian. The Sandstone Series has not yet yielded any fossils, and its more definite age has to be inferred from a comparison with the rocks of neighbouring regions.

The Lower Sandstone Series follows conformably upon the Lower Cambrian and is notable for its thick beds of magnesian limestone, commonly entirely composed of dolomite—intraformational conglomerates occur. These dolomites are often oolitic, and contain chert nodules and abundant stromatolitic forms, and they are correlated with the Durness Limestone and similar North American beds of Upper Cambrian and Lower Ordovician age. The land barrier separating the northern part of Great Britain with its North American fauna from the southern, seems to have extended north-east to South Finmarken, where it separated the northern sea of the Arctic Province with its characteristic dolomites from the southern in which the Kristiania beds of normal South British type were deposited. The volcanic rocks of West Finmarken are paralleled with the Lower Ordovician lavas of Central Norway and South Scotland.

The Lower Series was folded and faulted before the deposition of the Upper, which lies unconformably upon both the pre-Cambrian and the Lower Sandstones. The Varangerfjord fault runs east to west, with its downthrow side to the north, and these movements are correlated with the Middle Ordovician disturbances of Scotland and North America. The Upper Series derived its material from the highland south of the fault, which was a pre-Cambrian area, in part belonging to the land barrier, with remnants of the lower dolomite-bearing series.

The tillites occur at two horizons. The lower is a local deposit resting upon a grooved pavement, and containing ice-scratched boulders of gneiss, granite, and sandstone. Associated conglomerates contain pebbles of chert, and dolomite with oolitic and stromatolitic structures. The upper tillite contains ice-scratched boulders, but is of a different character; it is of very even thickness, extends over a wide area, and passes downwards into the even-grained ungrooved sandstones beneath, thus indicating a glacial deposit laid down under water from floating ice. The lower tillite, on the other hand, is of a continental type.

Dr. Holtedahl refers the tillites to some period between the Lower Ordovician and Upper Silurian, and lays stress upon the fact that they do not necessarily indicate a climate as cold as that of northern Norway at the present day. It is to be hoped that fossils will soon be found in these beds, and their exact age established beyond doubt. Their non-discovery up to the present is not incompatible with the age postulated, for considerable thicknesses of the Durness Limestone are barren, and limestones of undoubted Cambro-Ordovician age in North America of the same petrographical character have failed to yield fossils. Dr. Holtedahl's researches indicate that the tillites were formed before the Caledonian deformation attained its maximum, which was in Lower and Middle Silurian times, and that no general climatic change is to be inferred from them.

L. HAWKES.

THE ARBOUIN COPPER MINES AT CARDROSS. By L. C. BALL. Queensland Geological Survey, Publication No. 261. pp. 69. Brisbane, 1918.

THE Arbouin Copper-mines are situated in North Queensland, about 20 miles west of Mungana, the terminus of the Chillagoe Railway. Geologically the Cardross district is composed entirely of pre-Silurian schists and gneisses, and only to the east, about Mungana, are these overlaid by Silurian shales and limestones. The schists and gneisses have been invaded by an old series of basic dykes, now in the condition either of amphibolites or diorites, and later, probably at the time of the intrusion of the Permian granites by pegmatites and elvan dykes, accompanied by metalliferous lodes.

There are several belts of mineralization, and the trend of these and of the individual lodes is about north-east and south-west. The elvans, though having a trend generally at right angles to the lode direction, are evidently closely connected with the ore bodies, since in proximity to a dyke the lode is always richer, while in the absence of dykes the lodes are often barren. This relationship, coupled with the fact that the dykes often carry sulphides in workable amount, leads the author to the conclusion that the metalliferous solutions were introduced along the dyke fissures. The unoxidized sulphide ore consists for the most part of copper pyrites, mispickel and iron pyrites either branching and intergrown or finely granular, accompanied sometimes by tourmaline. An interesting variety, found on the Chieftain mine, contains magnetite, both in the form of round pellets and of threads intergrown with the copper pyrites.

The lodes show a very well-marked division into the three zones of oxidation, secondary enrichment, and sulphide ore. Since there is no carbonate in the country rock, the salt produced was the soluble sulphate, which was promptly carried down to the lower levels, leaving the oxidized zone for the most part free from copper compounds, except for the arsenate olivenite. This mineral, on one claim, provided quite a large yield of ore, a fact which constitutes somewhat of a curiosity in copper-mining.

The zone of enrichment includes chiefly the minerals tile ore, covellite, chalcocite, bornite, and copper pyrites; it is of irregular extent, but rarely exceeds a depth of 50 feet below ground water level. In the unoxidized portions of the lodes the richer ores are found in long narrow shoots, which may be several hundreds of feet long, but are only from 2 to 6 feet wide; in addition to the shoots the lodes contain large supplies of low-grade ore, which are now being worked on account of the uncertainty and irregularity of the shoots.

A fair amount of development work has been done on the field, and a smelter has been erected and worked for several short periods. The percentage of copper in the ores after hand-picking may rise as high as twenty, but the more usual level is about seven. The great difficulty, however, in mining at a profit is not the ore but the cost of transport to and from Cairns, the nearest port, which is so high as to make profitable working of the mines a very difficult matter.

W. H. W.

THE KENT COALFIELD: ITS EVOLUTION AND DEVELOPMENT. By A. E. RITCHIE. pp. x + 309, with illustrations, maps, and sections. Iron and Coal Trades Review, 1919. Price 7*s*. 6*d*.

THE world at large, and particularly the busier inhabitants of it, owe a great debt to compilers, and this debt is in no way reduced by the issue of Mr. Ritchie's book on the Kent Coalfield. The book is the result of the sifting of a vast mass of information, geological, statistical, and financial, which must have been, to a very considerable extent, in such inaccessible places as the files of the daily papers and company reports.

The author treats the subject historically, which is certainly the most convenient way of placing before us the story which he tells, but, as geologists, we could have wished that he had, at any rate, departed for a while from this course and gathered together the information from the various borehole sections which he gives. Of course the correlation of coal-seams is at present quite impossible, yet with the material now in hand it has been found to be possible to obtain at least a general view of the broad outlines of the structure of the coalfield. With this criticism we may pass on to the historical part of the subject-matter. The history of the field, from the early days when Godwin-Austen was trying to convince an unwilling public of the existence of coal in Kent, to the present stage of shaft-sinking and coal-producing, is admirably told, particularly that part of it which is connected with the financial transactions. These, to one unversed in such matters, read more like romance than sober fact, but no less amazing is the incredible persistency with which everyone connected with the coalfield continued to "back the wrong horse" on every possible occasion. Borings were put down on wrong theories, strata highly charged with water were assumed to be quite water-free, shafts were sunk without sufficient pumping-gear, in short almost every wrong assumption which could be made seems to have been made and acted upon; and yet there is now the Kent Coalfield, a going concern and one which would be now much more active were it not for the War and the threat of nationalization which is hanging over the head of so much colliery enterprise.

The book is very readably written, and the author is to be congratulated on having brought out the first connected account of the development of this very interesting area.

W. H. W.

THE SUBMERGED FOREST AT BOMBAY. By T. H. D. LA TOUCHE. Rec. Geol. Surv. India, vol. xlix, 1919, pp. 214–19, with plates 17–19.

ABOUT thirty years ago many tree-stumps, submerged about 20 feet below mean sea-level, were discovered during the excavation of the Prince's Dock, Bombay, and described in the *Records*, vols. xi and xiv. In 1910, during the extension of the Alexandra Dock to the south of the former site, more stumps were discovered and examined by Mr. La Touche. The stumps, 6 or 7 feet high, were rooted in a thin soil on the surface of disintegrated basalt, and embedded in blue clay, which included shells of *Ostrea cucullata* with valves united. The depth below high water-mark of the rock-surface is about 40 feet, which gives a minimum value for the total amount of depression. These two occurrences prove a considerable subsidence of the rocky floor, on the western side of Bombay harbour, apparently within human times, since one of the stumps seen in 1878 was partly burnt. This subsidence is interesting when considered in conjunction with the well-known occurrence of a raised beach in the same neighbourhood.

THE PORTO RICO EARTHQUAKE OF 1918. Report of the Earthquake Investigation Commission. By H. F. REID and S. TABER. Washington. 1919.

THE authors of this valuable memoir are experienced seismologists. Professor Reid wrote the second volume of the great report on the Californian earthquake of 1906, Mr. Taber has published accounts of several minor shocks in the United States. The earthquake here studied occurred without warning on October 11, 1918, shortly after 2 p.m. (Greenwich mean time), lasted two minutes, and was one of the most severe shocks felt on the island since its occupation by Europeans. Considerable damage to property occurred in the north-western corner of the island, and, from the distribution of the damage and from the evidence of the seismic sea-waves, the authors place the epicentre in the north-eastern part of Mona Passage (between Porto Rico and San Domingo). They consider that the earthquakes were caused by sudden fractures of the rocks forming the ocean-bed, and that the fractures probably occurred along an old fault. It is clear that the crust is still subsiding in the district surrounding the epicentre, for during the last half-century there has been a slow depression of the neighbouring coasts of Porto Rico. Soundings near this coast have revealed the existence of an extraordinary submarine valley running in a north-westerly direction and bounded by slopes which are so precipitous (amounting to 3½ kilometres in less than 15 kilometres) that they can only be explained as the result of faulting. A sudden fracture and vertical displacement of the rock along a fault or faults near the head or on one side of this depression would, as the authors remark, account for all the phenomena of the earthquake. The memoir, which is one of the most important of recent contributions to seismology, concludes with a description of the Virgin Islands' earthquakes of 1867-8, and a catalogue of all known earthquakes felt in Porto Rico and the Virgin Islands from 1772 to 1918. C. D.

ON PITCHBLENDE, MONAZITE, AND OTHER MINERALS FROM PICHHLI, GAYA DISTRICT, BIHAR AND ORISSA. By G. H. TIPPER. Rec. Geol. Surv. India, vol. i, 1919, pp. 255–62, with three plates.

A DESCRIPTION is given of an interesting occurrence of rare minerals in a large mass of pegmatite intrusive into garnetiferous mica-schists. The pegmatite consists of quartz, microcline, and greenish mica with pink garnets and apatite. The pitchblende remains as cores in rounded nodules of uranium ochre formed by its oxidation. A few examples were found of cubo-octahedral pseudomorphs of uranium ochre after uraninite. Torbernite and less commonly autunite are found encrusting mica, apatite, and other minerals. Monazite forms isolated crystals and masses in the felspar, often intergrown with columbite, mica, or apatite. Many of the crystals are unusually large; one crystal fragment weighed 500 grams, and a solid mass of 1·5 kilos was found; an average of three analyses gave 9·95 per cent ThO_2. Columbite builds fan-shaped aggregates in the felspar; the crystals are always singly terminated and often very large; one weighed over 6 kilos.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN. Vol. XV: ARSENIC AND ANTIMONY ORES. By H. DEWEY, with contributions by Dr. J. S. FLETT and G. V. WILSON. Memoirs of the Geological Survey. pp. iv + 59, with 2 figures and 1 plate. 1920. Price 3*s*. net.

THIS, the fifteenth volume of this valuable series, gives a comprehensive review of the British resources of ores of arsenic and antimony. The ores of arsenic have not been found in notable quantity in Britain outside Cornwall and Devon, but there the output is large, mainly as a by-product in the treatment of ores for tin and tungsten. Of late years the total production has averaged about 2,500 tons per annum of crude and refined arsenic, which is mainly used in the preparation of insecticides and to a less extent in glass-making; it is also employed in calico-printing, for hardening lead shot, and in medicine. All the arsenic is derived from mispickel.

An interesting account is given of the mines where arsenic is or has been produced in Cornwall and Devon, including a useful diagram, not, however, quite complete, of the lodes in East Pool Mine.

The production of antimony from the British mines is almost negligible in amount; the Glendinning Mine, in Dumfriesshire, here described by Mr. G. V. Wilson, has yielded a few tons. Dr. Flett gives an account of the antimony-bearing veins of the Knipes Mine, near New Cumnock, in Ayrshire, which carry stibnite in uncertain quantity. In Cornwall the antimony-bearing minerals jamesonite, bournonite, and tetrahedrite occur in small quantity, but these, as well as stibnite, are there mainly mineralogical curiosities.

REPORTS AND PROCEEDINGS.

MINERALOGICAL SOCIETY.

June 15.—Dr. A. E. H. Tutton, F.R.S., Past President, in the chair.

F. P. Mennell: "Rare zinc-copper minerals from the Rhodesian Broken Hill Mine, Northern Rhodesia." Copper minerals, including malachite, chessylite, copper-glance, and undetermined phosphates are of rare occurrence in the lead-zinc ore of this locality. Still rarer are the copper-zinc minerals aurichalcite and veszelyite; the latter forms minute, sky-blue, monoclinic crystals ($a:b:c = \cdot 971:1:\cdot 95$), and differs from the original mineral from Hungary in its colour and in containing little or no arsenic.

Professor R. Ōhashi: "Note on the Plumbiferous Barytes from Shibukuro, prefecture of Akita, Japan." This mineral, which is deposited as a white to brownish-yellow crystalline crust in the fissures and near the orifices of hot springs, is similar to the mineral recently called "hokutolite" from Taiwan (= Formosa); it contains 4·69 to 17·78 per cent of PbO, and is radio-active.

W. A. Richardson: "The Fibrous Gypsum of Nottinghamshire." The relation to the nodular types of gypsum of the fibrous veins of the mineral which are associated with every other type of gypsum deposit in the district, and occur at levels where there is no other development of the mineral, was considered. Most of these veins are regarded as having been formed shortly after the nodular deposits. The fibres grew upwards and downwards from a plane in the marl, and were probably deposited by descending solutions, being precipitated at planes of tension in a contracting medium. The veins of fibrous calcium carbonate or "beef" described by Dr. Lang show similar structure and field relations, and doubtless originated under similar conditions.

W. A. Richardson: "A new Model Rotating-stage Petrological Microscope." This instrument is intended as a substitute for the larger pre-War models, which at the present time could only be manufactured at very high prices. It is provided with a mechanical stage, interchangeable with a plane stage and a conventional sub-stage, and provision is made for rapid change from parallel to convergent polarized light. Owing to the reduction in size a rotation of 270 degrees only can be provided for the rotating stage.

W. Barlow: "Models illustrating the Atomic Arrangement in Potassium Chloride, Ammonium Chloride, and Tartaric Acid." In the case of the chlorides the suggested structure reconciles the X-ray phenomena with the crystalline symmetry. The arrangement proposed for tartaric acid agrees with the graphical formula of the chemists, and the molecular groups have the symmetry and relative dimensions of the crystals.

GEOLOGISTS' ASSOCIATION.

June 4, 1920.

"The Theory of Isostasy: its geodetic basis and its geological implications." By A. Morley Davies, D.Sc., F.G.S.

Plumb-line and pendulum anomalies. Historical summary: Bouguer, Petit, Pratt, Airy.

Static ideas of "compensation" become dynamic in hands of geologists: Osmond Fisher, Dutton.

Later geodetic developments: Hayford, Bowie, Burrard. Strength of the earth's crust: Barrell, Oldham.

Mistaken applications of the principle of isostasy by geologists. Great thickness of the shallow-water deposits, so far from being a consequence of isostasy, indicate its imperfection. Analysis of the case of the Weald.

July 2, 1920.

"On the Beds at the Base of the Ypresian (London Clay) in the Anglo-Franco-Belgian Basin." By L. Dudley Stamp, M.Sc., A.K.C., F.G.S.

Brief description of typical sections, showing the relation between the London Clay and the Lower London Tertiaries, throughout the London "Basin". The distinctive fauna of the Blackheath Beds contrasted with that of the underlying Woolwich Beds, and compared with that of the London Clay Basement Bed. Reconstruction of geographical conditions during Lower Eocene times. Evidence of the gradual but intermittent uplift of the Weald and its effect on the deposition of the Eocene beds.

The succession in Belgium. Description of new and typical sections. Oldhaven Beds. Close relation to deposits of London Area. The succession in the Paris "Basin". Remarkable similarity of geographical conditions compared with London. The Sinceny Beds—the homotaxial equivalents of the Blackheath (Oldhaven) Beds—have a similar fauna and were found under similar conditions.

The succession in the Hampshire "Basin". Connexion with Paris "Basin".

Faunal notes on the Blackheath–Sinceny Beds.

Summary: The London, Belgian, Paris, and Hampshire Eocene regions form parts of one great basin which has a common history. Essential to consider all parts of this basin in any discussion on Eocene rocks of one region. Blackheath–Sinceny Beds the result of the marine invasion of Ypresian times under special geographical conditions. Retained as a separate division but part of the Ypresian cycle. Marked change from conditions of formation of the underlying Landenian (Thanet Sands, Woolwich and Reading Beds).

"On the Stratigraphical and Geographical Distribution of the Sponges of the Inferior Oolite of the West of England." By L. Richardson, F.R.S.E., F.G.S.

CORRESPONDENCE.

GLACIAL EROSION OF SNOWDON.

Sir,—Professor Gregory's article on "The Pre-Glacial Valleys of Arran and Snowdon" in your April number does not give, as far as Snowdon is concerned, sufficient evidence for the form that he assumes for the Preglacial valleys. The question is, as he says, "merely how far the glaciers enlarged and deepened these pre-existing valleys." He quotes Ramsay as to the local glaciers "escaping from the high bounding-walls of the upper parts of their valleys", and infers from this that Ramsay thought "the valleys [that is the valleys in their existing form] were pre-Glacial". That was very likely Ramsay's opinion, but as he thought that the Snowdon glaciers merely scoured the pre-existing cwms and valleys, and as he gave practically no consideration to their possible excavation by glacial erosion, his views on the mooted question count for little.

Professor Gregory goes on to say: "The uplift of Snowdonia led to the erosion of canyons along the floors of the old valleys, the width of which indicates that they had been worn down to base-level and their walls cut backward before the Glacial period." It is here implied that the width of the Preglacial "canyons" is known; but as a matter of fact, their width as well as their depth is in question. The question cannot be satisfactorily solved simply by assuming, as Professor Gregory seems to do, that the canyons had some such width as the valleys possess to-day; for in that case the branch valleys would have established accordant junctions with them, and the present hanging relation of the branch valleys would remain unexplained. This difficulty Professor Gregory proposes to remove by assuming that "if the major valleys be regarded as a reticular system formed along fractures which gaped open at the uplift of the country . . . the [greater] depths of the main valleys as compared with some of their tributaries is a natural consequence of the more rapid denudation along the tectonic ruptures". But no evidence whatever is given to prove that the main valleys of Preglacial time were formed in this highly hypothetical manner, nor is any reticular valley system of such origin known elsewhere, for the newly deepened valleys of other broadly uplifted regions lie, in the vast majority of cases, along essentially the same courses that they followed before uplift. Indeed, until a reticular system of valleys occupying gaping fractures is shown to exist in some recently elevated region, the gratuitous supposition that the main valleys around Snowdon are of that extraordinary origin has no value.

A profile from Snowdon across the valley of Lake Cwellyn to Mynydd Mawr is introduced to illustrate the contrast between the theories of strong and of slight glacial erosion. "The areas in solid black represent the amount of solid rock removed on the alternative hypothesis that the valley had been excavated approximately to its present depth [and width] by pre-Glacial streams." Nothing is easier than to draw such a diagram; the difficulty comes in proving that the Preglacial valley truly had the width and depth there assigned to it. If it had any such width, its branch valley must have had an accordant junction with it, but as a matter of fact the branch hangs over the main valley. An additional difficulty would be found in justifying the assumption that the profile given for the Snowdon crest and for a cwm beneath it correctly represents the result of normal erosion in Preglacial time; yet such an assumption is made, for no "solid black" is added to indicate that the mountain profile has been perceptibly modified by glacial erosion.

It is then concluded that "according to this interpretation the topography of Snowdon at the beginning of the glaciation was essentially the same as it is now", and therefore that glacial erosion has been of small measure. Like the reticular system of fracture valleys this conclusion can have little value until a never-glaciated mountain district of altitude similar to that of North Wales is found, in which the effect of a sub-recent uplift in reviving normal erosion has been to produce huge cwms under sharp-edged mountain crests, and half-mile-wide side valleys hanging over still wider main valleys, with vigorous streams plunging down narrow clefts between the two. Mountains and valleys of such forms do not exist outside of deglaciated regions, and a great body of excellent evidence indicates that their peculiar forms are the product of glacial erosion.

W. M. DAVIS.

HARVARD UNIVERSITY,
CAMBRIDGE, MASS.

Recent Sinking of Ocean Level.

SIR,—Professor Daly's speculation in the June number of this Magazine regarding the possibility of a recent worldwide sinking of sea-level calls for exposition of the facts as regards the British Isles. The writer feels somewhat at fault in the matter as he has made a statement of results without evidence and expected it to be accepted. Under the circumstances Professor Daly can hardly be blamed for setting one statement against another, and considering that perhaps the facts may be as required by his theory. It should be pointed out, however, that there is not really, as Professor Daly has implied, any conflict between the writer's account of the so-called 25 ft. beach and those of Sir A. Geikie[1] and Hull. As regards Kinahan's discussion of the raised beaches of Ireland, it can confidently be said that what is not absolute error in it is so indefinite as to have little meaning. To him anything served as evidence of a shoreline, from a glacial corrie or a drift-bank to a limestone escarpment. The lowest of his horizontal shorelines is by his own statement only 4 feet above mean tide level, so that it is not clear

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[1] Anniversary Address to the Geological Society, 1904.

how it could be distinct from the modern shore. His statements, moreover, do not agree with those of Geikie and Hull.

Now to put the facts as briefly as possible. There are three sets of raised beaches traceable over considerable areas in the British Isles, (1) the pre-Glacial, (2) the Late Glacial, (3) the Neolithic (so-called 25 ft.). The submerged forests rest on the sediments of (2), and are overlain by those of (3). The Late Glacial and Neolithic beaches are thus quite distinct. The Neolithic beach is the best developed. It does not occur in the South of England and Ireland, where the only known raised shorelines are pre-Glacial. As regards the demonstration of the warping of the Neolithic beach, the writer has in his possession a notebook containing some hundreds of measurements made by H. B. Maufe and himself in various parts of the country, and covering in a rough way most of the coasts where the beach is found. The measurements were made either with reference to a comparable point on the modern shore or to high-water mark, or to both, where both were determinable. Many extended stretches of coast outside the area of the beach have also been examined without finding any trace of it. These observations have never been published because of their incompleteness. They are, however, amply sufficient to demonstrate the deformation of the beach and its approximation to or disappearance under sea-level along the periphery of its area of distribution. The exact position of the zero isobase is very difficult to determine, hence the writer's admission in a letter to Professor Daly that it might lie further south than shown in the diagram referred to. The average gradient is only one or two inches to the mile.

As regards dates, which Professor Daly expressly asks for, and climatic conditions, which must interest him, we have fortunately some very definite facts, which are in agreement with observations on the continent of Europe. The beach was formed in Early Neolithic or Campignian times, and elevated to nearly its present surface in late Neolithic times. Campignian implements are found embedded in it 12 feet below the surface, and polished stone axe-heads lie on its surface not many feet above present high water-mark. Its fauna indicates a climate some degrees warmer than that of the present day.

With Professor Daly's contention that eustatic movements of ocean level have taken place in recent geological times, the writer is in perfect agreement, but that the latest movement has been a negative one is not supported by the evidence in this country or on the continent. Outside the zero isobase of the Neolithic beach, in Ireland, England, and Denmark, Neolithic remains are found beneath sea-level, indicating a distinct positive movement. The widely distributed submerged forests dating from early Neolithic or immediately pre-Neolithic times onwards provide very good evidence of a general submergence. The very puzzling Micmac terrace, in its horizontality so unlike the post-Glacial beaches of

Europe, has naturally led Professor Daly to a different conclusion. Why it alone should be undeformed, lying as it does among the highly warped shorelines of North America, is a mystery which the tracing of it into other areas may ultimately solve. Its parallelism to the modern shore is the more puzzling, as Gilbert seems to have proved that the warping of the Great Lakes Region is, like that of Scandinavia, still progressing. As regards the very widely distributed raised shorelines and reefs of tropical seas, the writer has long thought that they are more probably the equivalent of the pre-Glacial shoreline of Europe than of any of the later raised beaches. Maufe was inclined to hold the same view when he was working on the raised reef at Mombasa. If this is the case, the conclusion must be that the ocean, after the Glacial oscillations, has returned to a level a little lower than that of pre-Glacial times.

W. B. WRIGHT.

DUBLIN.
June 15, 1920.

[We regret that this letter was received too late for insertion in the July number.—ED. GEOL. MAG.]

THE BOURNEMOUTH CLIFFS.

SIR,—I have no desire to prolong this discussion, but as I have been asked where photographs of the cliffs, as they appeared about thirty years ago, may be seen, I should like to refer those who are interested to one illustrating an article on "Scientific Aspects of Bournemouth", which appeared in *Research* of December 2, 1889.

Yours faithfully,
C. CARUS-WILSON.

OBITUARY.

GEORGE SWEET, F.G.S.

BORN 1844. DIED 1920.

MR. GEORGE SWEET, who recently died at the age of 76, was born at Salisbury, England, but spent most of his life as a manufacturer of pottery near Melbourne, Australia. He was a keen geologist, and was second in command of the second Funafuti expedition under Professor Edgeworth David. He also made extensive collections of fossils from the Carboniferous and Cretaceous strata of Queensland, and investigated the Permo-Carboniferous glacial beds of Bacchus Marsh. In 1905 he was President of the Royal Society of Victoria.

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PROF. J. W. GREGORY, D.SC., F.R.S.
F. H. HATCH, PH.D., M.INST.M.M.
PROF. J. E. MARR, SC.D., F.R.S.
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HENRY WOODS, M.A., F.R.S.
DR. A. SMITH WOODWARD, F.R.S.

SEPTEMBER, 1920. no. 9

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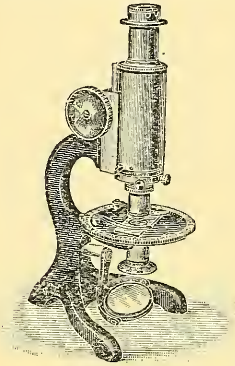


THE
GEOLOGICAL MAGAZINE
VOLUME LVII.

No. IX.—SEPTEMBER, 1920.

EDITORIAL NOTES.

IN his Presidential Address to the British Association at Cardiff, Professor Herdman gave an admirable summary of the modern developments of his special subject, Oceanography. This new science comprises portions overlapping from many other fields of research, and Professor Herdman naturally dealt at length with the biological side of it, but even the biology of the deep sea affords evidence as to geological problems, while the geological value of physical oceanography needs no extended demonstration.

* * * * * *

THE President of Section C, Dr. F. A. Bather, devoted his address to a comprehensive review of the present position of biological science from the point of view of evolution. This subject naturally appeals very strongly to a palæontologist, but Dr. Bather did not by any means confine himself to extinct forms. He also quoted modern instances where necessary. We hope to give in a later number a summary of some of the main points brought forward in this admirable address, which should do much to stimulate interest in the newer and more philosophical ideas which are now exerting so much influence in the development of palæobiology.

* * * * * *

IN our correspondence columns we print a letter from Professor Marr, inquiring whether any of our readers can assist him in discovering the whereabouts of certain implements found by the late Mr. S. B. J. Skertchly from deposits around Brandon and Mildenhall, in Suffolk, and supposed to be of Mid-Glacial age. It is unnecessary to enlarge on the importance of these implements, if still in existence, and we hope some information may be forthcoming.

* * * * * *

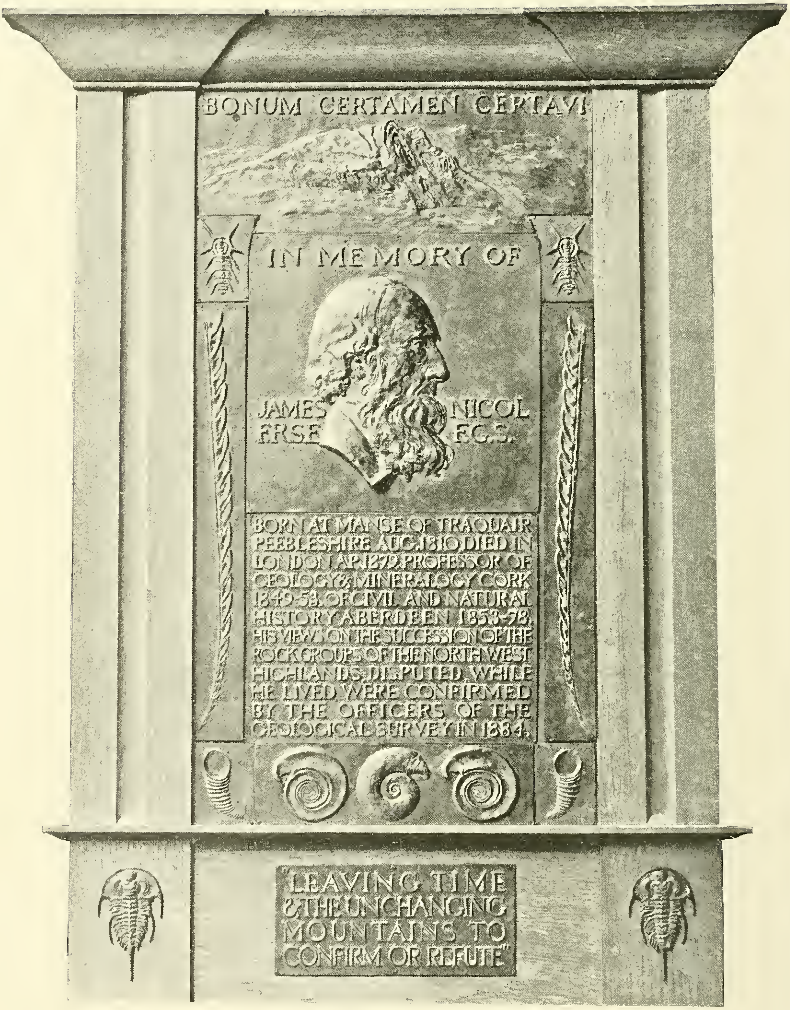
THE loss last month of Sir Norman Lockyer, K.C.B., F.R.S., deprives us of a distinguished astronomer and physicist and the founder, in 1869, of the well-known weekly scientific journal *Nature*, whose "jubilee" was held last year. Born at Rugby in 1836, he was appointed a clerk in the War Office in 1857, Director of the Solar Physics Observatory, South Kensington, 1885–1913, President of the British Association 1903–4, Director of *eight* English Eclipse Expeditions (between 1870 and 1905), and author of numerous books and papers on astronomy and physics.

* * * * *

DEATH has deprived us of Professor John Perry, D.Sc., F.R.S., late of the Royal College of Science, South Kensington (1850–1920), who, with Professors Ayrton and John Milne, was among the first on the staff of the Imperial College of Science, Tokio, Japan; Professor of Mathematics and Engineering, City and Guilds of London Technical College, Finsbury; President of the Physical Society; for many years General Treasurer of the British Association; author of numerous scientific papers, a most popular lecturer, and beloved by a wide circle of men of science.

* * * * *

THE Mining Industry Act, 1920, which is the latest version of the measure for the establishment of a Ministry of Mines, has undergone a good deal of modification in its passage through Parliament. Some of these changes have to a certain extent met the objections raised in a former issue of the Magazine. Thus we find that it is now provided that two advisory committees must be appointed by the Board of Trade, one to deal with coal, the other with metalliferous mining. The constitution of the coal committee is set out in detail; out of a total twenty-four members only one is to be a mining engineer, and there is provision for the inclusion of a number of faddists of various kinds. There is a delightful vagueness about the clause "three [members] shall be persons with expert knowledge of medical or *other* science": the italics are ours. As to the constitution of the committee on metalliferous mining nothing is said. Section 21, subsection 2, provides that no information with respect to any particular undertaking shall be included in any published report. This is a retrograde step, since in Section 10 of the Metalliferous Mines Act of 1872 power is given to the Secretary of State to collect statistics, and there is no limitation of his power to publish them. If this new provision is enforced no details can be given as to the output of particular mines, as has hitherto been done, for example, in the case of hematite mines.



Memorial Tablet erected to
PROFESSOR JAMES NICOL, F.R.S.E., F.G.S.,
in the University of Aberdeen, 1st July, 1920.

Designed and executed by Alice B. Woodward.

The Nicol Memorial.

(PLATE VI.)

A MURAL tablet, to the memory of Professor James Nicol, F.R.S.E., F.G.S., formerly of Aberdeen University, was unveiled by Dr. John Horne, F.R.S., in Marischal College, and entrusted to the Principal, Sir George Adam Smith, on July 1.

The memorial was presented by a number of well-known geologists who were his friends and admirers and desired to commemorate in some permanent form their high estimation for this distinguished teacher in the University during a quarter of a century, and also to record his original contributions to Scottish geology, the value and importance of some of which were not fully appreciated and confirmed until after his death.

The memorial (see Plate VI) is placed side by side with that of Professor Nicol's successor, Professor Henry Alleyne Nicholson,[1] in the same chair, and was designed and executed by the same artist, Alice B. Woodward, daughter of Dr. Henry Woodward, F.R.S., in the form of a bronze tablet in repoussé-work mounted on oak (measuring 4 feet by 3 feet), bearing the modelled profile medallion of Nicol with name and titles. Beneath the portrait in close raised letters, in twelve lines, is given an epitome of his career with dates, as follows:—

> BORN AT MANSE OF TRAQUAIR
> PEEBLESHIRE AUG. 1810, DIED IN
> LONDON AP. 1879. PROFESSOR OF
> GEOLOGY & MINERALOGY CORK
> 1849–53. OF CIVIL AND NATURAL
> HISTORY ABERDEEN 1853–78.
> HIS VIEWS ON THE SUCCESSION OF THE
> ROCK GROUPS OF THE NORTH-WEST
> HIGHLANDS, DISPUTED WHILE
> HE LIVED, WERE CONFIRMED
> BY THE OFFICERS OF THE
> GEOLOGICAL SURVEY IN 1884.

Below is quoted a phrase used by the Professor himself—

> "LEAVING TIME AND THE UNCHANGING
> MOUNTAINS TO CONFIRM OR REFUTE."

Above, the tablet bears the words—

> BONUM CERTAMEN CERTAVI,

and in low relief is given a sketch of Na Tuadhan, a mountain north of Ben More Assynt, showing typical foldings.

On the border of the tablet are figures of Graptolites, *Monograptus vomerinus* Nich. and drawings of *Maclurea Peachii* Salter and two of the Trilobites, *Olenellus Lapworthi* and *Olenelloides armatus*, discovered in 1892–4 by the Geological Survey.[2]

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[1] See Memorial Tablet to Professor H. A. Nicholson, F.R.S., GEOL. MAG., 1903, pp. 451–2, Plate XXI.

[2] See Drs. B. N. Peach & J. Horne, "*Olenellus* Zone in the North-West Highlands of Scotland": Quart. Journ. Geol. Soc., vol. xlviii, 1892, pp. 227–41, with sections and plate v (Trilobites). Id., addition to fauna of same, vol. l, 1894, pp. 661–75, pls. xxix–xxxii (Trilobites).

On behalf of the subscribers, Dr. John Horne, F.R.S., addressed the Principal, Sir George Adam Smith, as follows :—

Sir George,—We have met here to-day to do honour to Professor James Nicol, who for more than a quarter of a century was one of the teachers of Natural Science in this University, and whose contributions to Scottish geology were of the highest value. He was a remarkable example of the best traditions of Scottish University life, for, in addition to the prime duty of instructing students, he regarded the prosecution and encouragement of original research as an essential feature of the work to be done by a scientific department.

This memorial is intended to be a permanent record of the value of his contributions to the solution of the problem of the geological structure of the North-West Highlands. In the first half of last century that region was visited by Macculloch, Murchison and Sedgwick, Hay Cunningham and Hugh Miller, who had described the picturesque mountains of red sandstone, overlain by quartzites and limestones, in the west of the counties of Sutherland and Ross. They recorded that these unaltered strata rest upon a platform of crystalline gneiss and schist, and are succeeded eastwards by metamorphic rocks that stretch across the Great Glen to the eastern border of the Highlands.

The discovery of fossils in the Durness limestones in the north of Sutherland (in 1854) by Mr. Charles Peach raised questions of vital geological importance connected with the structure of that region and the age of the crystalline schists associated with these limestones.

Nicol's field work in the North-West Highlands began in 1855, not long after his appointment to the Professorship in this University. His first examination of the ground was carried out in association with his friend Sir Roderick Murchison, but all his subsequent work was done by himself, for they differed as to the interpretation of the structure.

Adopting the determination of the fossils made by J. W. Salter, the palæontologist of the Geological Survey, Murchison referred the quartzites and limestones to the Silurian system. He further contended that as the fossiliferous limestones passed normally below the crystalline schists to the east, therefore these schists themselves must belong to the same system. Hence, with one bold sweep of the brush, Murchison coloured as Silurian the extensive region stretching from near Durness to Stonehaven, and from Fraserburgh to the Mull of Kintyre. This interpretation involved a radical change in the geological map of Scotland.

Nicol's interpretation was fundamentally different. With untiring energy he continued his work in the field for several years and issued a series of papers containing the results of his researches. From time to time he modified his views, abandoning positions which he found to be untenable, and stating the evidence for changing his opinions. In the development of his researches he showed sterling honesty of purpose.

His work in the field may be summed up in two propositions. First, he showed that the red sandstone formation, which he named the "Torridon Sandstone", was separated from the overlying quartzites and fossiliferous limestones by a great unconformity, implying a gap in the geological record. This important structural feature was traced by Nicol for a distance of one hundred miles from the north of Sutherland to Loch Kishorn. Second, he contended that no conformable upward succession from the fossiliferous limestone to the overlying schists is to be found. To quote his own words: "The line of junction, where this conformable succession is said to occur, is clearly a line of fracture, everywhere indicated by proofs of fracture, contortion of the strata, and powerful igneous action."

Such widely different interpretations gave rise to keen controversy. The progress of geology, like that of other sciences, is bound up with controversy. The brethren of the hammer fight keenly; indeed, the *odium geologicum* rivals at times the *odium theologicum*.

Murchison's order of succession, which was supported by Sir Andrew Ramsay, Professor Harkness, and Sir Archibald Geikie, met with general acceptance because it furnished such a simple solution of the problem.

In 1878 the controversy was reopened and Murchison's position was shown to be untenable by several investigators, of whom the most prominent was the late Professor Lapworth,[1] followed by Dr. Callaway,[2] Professor Bonney,[3] Dr. Hicks, and others.

In 1883 the Geological Survey began the detailed mapping of that region. The results of their work completely confirmed Nicol's main conclusions.[4] We now know that the structure of that mountain chain is intensely complicated, far more complicated than Nicol imagined. Under extreme lateral pressure the rocks have behaved like brittle rigid bodies; they have snapped

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[1] Professor Charles Lapworth, "The Secret of the Highlands": GEOL. MAG., 1883, pp. 120–8, 193–9, 337–44. "On the Stratigraphy and Metamorphism of the Rocks of the Durness–Eireboll District": read at the Ordinary Meeting of the Geologists' Association, July 4, 1884, by Professor C. Lapworth; printed as read, with a few words added in brackets for clearness of description, by J. J. H. Teall, GEOL. MAG., 1885, pp. 103–6. Professor C. Lapworth, "The Close of the Highland Controversy": GEOL. MAG., 1885, pp. 97–103.

[2] Dr. Callaway, Quart. Journ. Geol. Soc., May, 1881; GEOL. MAG., 1883, p. 139. Id., "Torridon Sandstone and Ordovician Rocks of the Northern Highlands": Q.J.G.S., vol. xxxviii, 1882, pp. 114–17. Id., "Age of the Gneissic Rocks of the Northern Highlands": Q.J.G.S., vol. xxxix, 1883, pp. 355–414.

[3] Professor T. G. Bonney, "Lithological Character of Scottish Rocks" (Dr. Hicks' Collection): Quart. Journ. Geol. Soc., vol. xxxix, 1883, pp. 159–66; (and Dr. Callaway's Collection), vol. xxxix, pp. 414–20.

[4] Drs. B. N. Peach & J. Horne: "Preliminary Report on the Geology of the Durness–Eireboll District": *Nature*, November, 1884, vol. xxxi, p. 19.

and have been driven westwards in successive slices, so that crystalline gneiss and schist are made to rest upon fossiliferous strata of Cambrian age. But Nicol's main contention was proved beyond doubt that there is no conformable sequence in the North-West Highlands from the quartzites and limestones into the overlying schists. In grappling with the structure of this old mountain chain there can be no question that Nicol displayed the qualities of a great stratigraphist.[1]

Since the publication of the results of the Geological Survey work, that region has been visited by many of the leading geologists in Europe and North America, who have been profoundly impressed with the light which it throws on the building of an old mountain chain by folding and terrestrial displacements.

It is a source of genuine pleasure to me to present this memorial on behalf of the subscribers to you, Mr. Principal, for the preliminary report on the geology of the Durness–Eireboll district, published in *Nature* in 1884 by my old friend and colleague Dr. Peach and myself, led to the final abandonment of the Murchisonian hypothesis.

In the custody of yourself and your successors it will recall the labours of one whose name is inseparably linked with the solution of one of the great problems in British geology.

* * * * * * *

The following is a brief abstract of Professor Nicol's life, taken from his obituary by Professor Lapworth (Quart. Journ. Geol. Soc., 1880, Proc., pp. 33–6), and may serve to show the leading features in his career and explain the silence which marked the latter years of his strenuous life.

More than a century ago James Nicol was born at Manse of Traquair, Peeblesshire, in 1810. His father, the Rev. James Nicol, was well known for his poetical writings. After his father's death in 1819, young Nicol lived with his family in Inverleithen, where his early education was completed by the Rev. Mr. Pate. His rambles amid the bold and picturesque scenery of the district led him early to study its geology. The absence of fossils and of clear sections in these old rocks directed Nicol's attention more especially to their mineralogical aspect, still further encouraged by his subsequent attendance on the classes of Professor Jameson. He entered the University of Edinburgh in 1825, where, after passing the Arts and Divinity courses, he went to Germany and studied at the Universities of Berlin and Bonn. On the conclusion of his University training he returned to Scotland, and devoted himself to the geology of the valley of the Tweed, and in 1841 he was awarded prizes by the Highland Society for his essay on the Geology of

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[1] Quart. Journ. Geol. Soc., vol. xii, 1857, pp. 17–39, with sections; and C. Lapworth, "Theory of Professor Nicol": GEOL. MAG., 1888, p. 123.

Peeblesshire,[1] and subsequently for one on the Geology of Roxburghshire.

During the ensuing years he made extensive geological journeys throughout Scotland, more especially in its southern portions. The results of these investigations were published in the form of *A Guide to the Geology of Scotland*, illustrated by plates and a small geological map of Scotland.

In 1847 James Nicol was appointed Assistant Secretary to the Geological Society of London, and for two years he edited the "Quarterly Journal" of the Society. Here he gained the friendship of many of that illustrious group of British geologists which then assembled at its meetings. In this congenial atmosphere Nicol's mineralogical studies were prosecuted with increased ardour; and in 1849 he published his well-known textbook of mineralogy.

First among his geological friends stood Sir R. Murchison, and through his influence, and that of Sir H. De la Beche and Sir Charles Lyell, Nicol was appointed in 1849 to the post of Professor of Geology and Mineralogy in Queen's College, Cork. But in 1853 he relinquished the post for the more lucrative position of Professor of Natural History in the University of Aberdeen, which he retained till his death in 1879.

In spite of his predilection for mineralogy, it is beyond question that Nicol will be remembered less for his mineralogical works than for his numerous and valuable memoirs upon the stratigraphy of Scotland. His papers upon the Geology of the Southern Uplands of Scotland are of especial interest and value. In 1848 he published a memoir "On the Rocks of the Valley of the Tweed" (Quart. Journ. Geol. Soc., iv, p. 195), demonstrating their fossiliferous character, and a general view of the entire succession among the transition rocks of South Scotland, and applying to them for the first time the title of "Silurian". In 1849 he communicated a memoir "On the Silurian Rocks of the South-East of Scotland" (Quart. Journ. Geol. Soc., vol. vi, p. 53), in which for the first time Graptolites were figured from these ancient deposits. In 1850 he accompanied his friend Sir R. Murchison in a tour through the Southern Uplands, and aided him in his detailed investigation of the geology of the fossiliferous Girvan area. In 1852 he communicated a complete résumé of the results of his extended researches into the geological structure of the Southern Uplands, illustrating it by the first complete transverse section through the Silurian rocks from the Pentlands to the Cheviots. A reduced copy of this section illustrated all the subsequent editions of Murchison's *Siluria*, and stood substantially unmodified in the official publications on South Scottish geology, until the true order of succession, based on the graptolites, was established by the late Professor Lapworth.

During his residence in the University of Aberdeen Nicol

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[1] In the first of these publications the presence of fossils in the Lower Palæozoic rocks of the Inverleithen district was first made known.

transferred the sphere of his geological investigations to the metamorphic rocks of the Highlands, which in 1844 he had suggested were probably of the same geological age as those of the Southern Uplands. In 1855 he published his paper "On the Sections of Metamorphic and Devonian Rocks of the Eastern Extremity of the Grampians" (Quart. Journ. Geol. Soc., vol. xi, p 544).

The same year he visited the well-known Torridon and Durness area in the North-West Highlands in company with Sir R. Murchison, in order to verify Mr. Peach's discovery of fossils in the metamorphic limestone of that region. On his return he communicated an independent memoir to the Geological Society (Quart. Journ. Geol. Soc., vol. xiii, p. 17), in which he claims to have published for the first time their order of succession, viz.: (*a*) Lower Gneiss; (*b*) Conglomerate and Red Sandstone; (*c*) Quartzite; (*d*) Limestone, overlain by (*e*) an Upper Gneiss. Arguing mainly from the petrographical character of these rocks, he threw out the suggestion that the Torridon Sandstone might be of Devonian age, and that the overlying limestone and gneiss might be of the age of the Lower Carboniferous. After Mr. Salter's demonstration that the fossils of the Durness Limestone were not Carboniferous, but belonging to the deepest zone of Murchison's Silurian, Nicol again visited the North-West Highlands. In a memoir giving the chief results of this expedition (Quart. Journ. Geol. Soc., xvii, p. 85) he retraced his former admission of an Upper Gneiss, superior to the Durness Limestone; and claimed to have proved that the line of demarcation between the Durness series and the eastern gneiss of Central Sutherlandshire is actually a line of fault, the Torridon and Durness strata always overlying or abutting against, but never dipping under, the eastern gneiss. These opinions led to a keen controversy between himself and his old friend Sir R. Murchison; but after the publication of two additional memoirs on the subject in 1862 and 1863, in which he defended his view that the central gneiss of the Highlands is of the same general geological age as the Lewisian gneiss of the Outer Hebrides, and that the only metamorphic strata that can safely be called "Silurian" are the less altered rocks upon the outer borders of the Highlands, he ceased to contribute papers to the Society upon the subject. A little work, *On the Geology and Scenery of the North of Scotland*, contains his last published words upon the subject.

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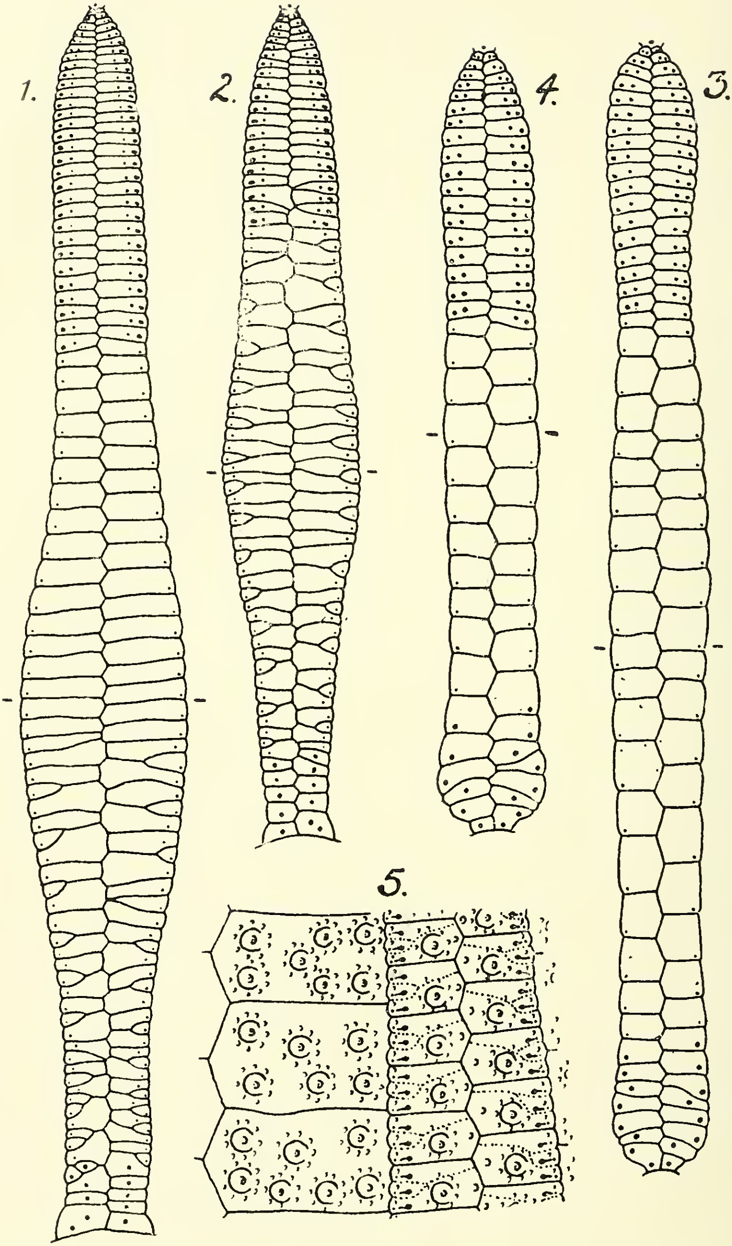
"The Close of the Highland Controversy," written by Professor Lapworth (see GEOL. MAG., 1885, pp. 97–106), and the admirable but brief address by Dr. John Horne (*ante*, pp. 388–90), furnish a suitable note to Professor Nicol's life and researches, most of the friends and contemporary actors in which have now, like himself, "ceased from their labours." But the value of their conclusions have left a permanent impress for good on the modern school of geological thought and science which can never be forgotten.—H.W.

Plate VII.



H. L. H. del.

Ambulacra of *Apatopygus*, *Oligopodia*, and Young *Echinolampas*.

To face p. 393.]

ORIGINAL ARTICLES.

Morphological Studies on the Echinoidea Holectypoida and their Allies.

X. ON *APATOPYGUS* GEN. NOV. AND THE AFFINITIES OF SOME RECENT NUCLEOLITOIDA AND CASSIDULOIDA.

By Herbert L. Hawkins, D.Sc., F.G.S., Professor of Geology, University College, Reading.

(PLATE VII.)

1. Introduction.

WHILE collating the plates in a recently acquired copy of the *Revision of the Echini* (A. Agassiz, 1872–4), I noticed with surprise a representation of complex ambulacral structure in "*Echinobrissus*" *recens* (pl. xiv *a*, figs. 3–4). A style of plate-grouping essentially similar to that in *Echinoneüs* (tab. cit., figs. 7–8) is portrayed as affecting all the extra-petaloid parts of the five areas, and encroaching slightly on the distal parts of the petals. No reference to this unusual condition occurs in the text. As the proofs of my recent paper on ambulacral structures (Phil. Trans., B, vol. 209) were in my hands at the time, I was immediately impressed by the remarkable resemblance between "*E.*" *recens* and the Cretaceous *Trematopygus*—a correspondence by no means restricted to ambulacral plating, but involving all coronal features save the orientation of the peristome.

Within an hour of the discovery a letter was dispatched to Dr. H. L. Clark, of the Museum of Comparative Zoology, Cambridge, Mass., asking if he could confirm the presence of the structure indicated, and begging for any fragments of "*E.*" *recens* that could be spared. By return mail he sent me entire tests of three rare Echinoids, "*E.*" *recens* (to him an *Oligopodia*), *Oligopodia epigonus*, and *Rhynchopygus caribœarum*. He encouraged, nay commanded, me to work my will on the beautiful specimen of the first-named species, even if pulverization were the result, and placed but few restrictions on my treatment of the others. Some idea of the disinterested generosity shown can be conveyed on two counts. In the first place the specimens are recent forms on which Dr. Clark has been working lately, thereby "staking a claim" in them whose justice all would admit. But he handed them over to the tender mercies of a palæontologist who had not the temerity to ask for them! Secondly, Agassiz Museum possesses only four specimens of "*E.*" *recens* (one of which I was instructed to destroy), two of *O. epigonus* (the better of which, figured in the *Revision*, pl. xix *b*, figs. 4–6, is in my hands), and two of *R. caribœarum*.

The liberty and fraternity of science could scarcely have had more convincing exposition. In publicly expressing my gratitude to Dr. Clark and the Museum with which he is connected, I feel constrained to hope that the spirit herein manifested may inspire an ever-growing *ecclesia* of individuals and institutions. A Museum whose aim is to acquire and store away a miserly hoard of rarities is in danger of becoming a mausoleum rather than a radiant centre of vitality in research; the individual who fails to welcome discoveries, even when they might have been his own, is no apt disciple, still less a true apostle, of the creed of science.

Of the three specimens sent for study "*O.*" *recens* is now in ruins (though even yet beautiful); *O. epigonus* has acquired a coloration unlike that secreted by any known Echinoid, and has unfortunately lost its apical system; while *R. caribœarum* has suffered removal of many of its radioles. It is my earnest hope that the following notes may atone in some measure for the damage done, and convey in the most acceptable form my thanks for the prompt and almost reckless generosity that enabled me to investigate material at once so precious and so interesting.

2. Apatopygus recens (Milne Edwards).

This species was introduced by Milne Edwards in 1836 (Cuvier, Regn. Anim. Zooph., pl. xiv, fig. 3), under the name *Nucleolites recens*. At that date *Nucleolites* was a broad generic term covering all Irregular Echinoids which have the periproct on the adapical surface; but in this particular case the close superficial similarity between *N. recens* and such fossil forms as *N. scutatus* made application of the name unusually appropriate. D'Orbigny in 1854 (Rev. Mag. Zool.) automatically replaced *Nucleolites* by the pre-Linnean *Echinobrissus*, but no reasoned attempt at better generic precision was made until 1889, when Duncan (Journ. Linn. Soc., vol. xxii) proposed *Oligopodia* as a subgenus, including the two recent species of "Nucleolitidæ" then known, *recens* and *epigonus*. In 1904 Hamann (Bronn's *Thierreichs*) raised *Oligopodia* to generic rank, and restricted it to *O. epigonus* (Martens), which thereby became the genotype. "*Echinobrissus*" *recens* was left in *Nucleolites* by Hamann, but Clark (1917, *Hawaiian and other Pacific Echini*, p. 107), believing *recens* and *epigonus* to be congeneric, and "quite different from typical *Nucleolites* of Lamarck", placed both under *Oligopodia*.

While concurring in Clark's opinion that both are incapable of bearing the name *Nucleolites*, I am fully convinced that they are so far from being congeneric that family, and indeed ordinal, distinctions separate them. The reasons for this belief are subjoined, but the systematic sequel can be indicated here. *Nucleolites epigonus* Martens is the lecto-genotype (Hamann, 1904) of *Oligopodia* Duncan, 1889. *Nucleolites recens* M. Edwards is certainly not a *Nucleolites* in the accepted sense of the term, and is even less akin to *O. epigonus*. A new generic name is thus necessary for *N. recens*, unless that species can be shown to belong to some other genus already diagnosed. The latter condition does not obtain, so far as I can determine, so that I hereby establish the new genus *Apatopygus*,[1] whose genotype and only known species is *Nucleolites recens* Milne Edwards, 1836. A detailed diagnosis of the genus concludes this section of the paper.

The description of *Apatopygus recens* (sub *Echinobrissus*) given by A. Agassiz (*Revision,* pp. 556–7) is sufficiently full and in agreement with the specimen before me to serve with but little comment. The description of the peristome and its surroundings is accurate, but Agassiz' use of the term "phyllode" might prove misleading. There is no more trace of phyllodal qualities, whether of plating or pore-disposition, in the orad parts of the ambulacra than occurs in an ordinary Spatangid. The proximal pores are appreciably larger than the others, and tend to perforate their ambulacrals in the median line rather than near the adradial sutures; but the pores show less tendency towards triserial arrangement near the peristome than on the rest of the adoral surface, while the plating is almost perfectly simple and "Cidaroid" in the region where the pores increase in size. With regard to the interambulacral parts of the peristome-margin, there can be no doubt that Agassiz' remark that "no buccal bourrelet had been developed" is an under-statement. As far as such a condition is conceivable it may be said that "bourrelets" are positively absent—the proximal interambulacrals are exceptionally thin in their invaginated parts, resembling those of *Echinonëus* more than those of any other recent Echinoid with which I am acquainted, and exceeding them in delicacy. The quality expressed in the generic description (loc. cit., p. 556) "Floscelle rudimentary; no well-marked bourrelets" would, to my mind, be better abbreviated to the bare statement "no floscelle".

The nature of the ambulacral plating, which is roughly indicated in Agassiz' figures, but not mentioned in the text, seems to me to provide the most unusual and distinctive feature in *A. recens*. Analyses of one of the longest areas (I) and the shortest area (III) are here given (Plate VII, Figs. 1 and 2). As far as indications go, area II (which is almost midway between the extremes in point of length) resembles the latter more closely than the former. In all ambulacra, practically the entire extent of the adoral parts (excluding the peristomial portions above mentioned) display typically "Pyrinid" plating (see Hawkins, Phil. Trans., 1920), the demi-plates often undergoing great reduction. In area I this condition ceases just below the ambitus, and the adapical part of the area is built of simple primaries, some of which (below the petals) may be almost half as high as broad. The petal consists of thirty plates in each column, perforated by dissimilar pore-pairs. In area III, Pyrinid structure persists up to, and even into, the petaloid region with characters indistinguishable from those present adorally.

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[1] *ἀπατάω*, I deceive, and *-pygus*, normal suffix for genera of this group.

There are twenty-one or twenty-two plates in each column of the petal. Three or four of the distal plates of this region show incipient Pyrinid grouping, while a trifling imperfection of alternation affects both columns quite near the apex. (This last may well be but an individual irregularity.) The indications of structure given in Agassiz' figures are therefore confirmed (broadly speaking); but he represents Pyrinid plating as continuous to the petals in all five areas, while it certainly does not extend above the ambitus in areas I and V in the specimen before me, and seems not to reach the petals in II and IV.

The two features described above contain sufficient evidence for generic separation of *A. recens* from *O. epigonus* (Pl. VII, Figs. 3 and 4), although many others could be cited. In the latter species there is a perfectly definite floscelle, with expanded (though structurally simple) phyllodes and well-marked, typical interambulacral bourrelets. There is no trace of ambulacral complexity above the phyllodes; all ambulacrals between these and the petals are about as high as broad, and in consequence the number of podial pores is very small. All five petals are of the same length, and contain the same number of plates; while the petaloid pores are large and perfectly similar. The name *Oligopodia* is eminently appropriate for *epigonus*, but it would be grotesque to apply it to *recens*, where the number of ambulacral plates (and podia) is vastly in excess of expectation for so small a form. *O. epigonus* is a typical "Cassiduloid", and resembles *Rhynchopygus* and *Echinolampas* in ambulacral characters, as in many others. As Agassiz remarked, it is closely similar to the Cretaceous genus *Caratomus*. The affinities of *Apatopygus* will be discussed in the next section, but a diagnosis of the genus is now possible.

APATOPYGUS gen. nov., Hawkins, 1920.

Genotype and sole species, *Nucleolites recens*, M. Edwards, 1836.

Nucleolitoida, Nucleolitidæ. *Test* depressed, subquadrate, with greatest width behind the apex. *Ambitus* rounded, adapical surface rising to a low, almost median summit; adoral surface slightly tumid, strongly invaginated at the peristome. *Apical system* eccentric anteriorly, built of five small oculars and four genitals, of which the madreporic plate occupies the centre of the system, and just separates the posterior oculars. *Peristome* deeply invaginate, eccentric anteriorly, transversely elliptical, with thin marginal plates. *Periproct* longitudinally elliptical, situated in a deep sulcus to which it forms the apicad wall, about midway between the apex and the posterior margin of the test. Anus surrounded by a many-plated membrane, the largest plates being posterior and external. *Interambulacra* wide, built of fairly low plates bent near the median line of each column. Proximal orad interambulacrals large, single, and very thin. Tubercles large for a Nucleolitoid, scrobiculate, imperforate; arranged in quincunx on apicad and orad plates. *Ambulacra* petaloid, narrow, widest at the ambitus. Posterior petals longer than anterior; that of area III the shortest. Petaloid pores dissimilar, outer pores elliptical and larger than the inner, round, pores. Extra-petaloid pores single and small, three or four in the peristomial invagination being slightly larger than the rest, but not attaining the size of the outer petaloid pores. Pore-series irregularly uniserial (with tendencies to triserial arrangement below the ambitus), convergent adorally. Proximal orad plates primaries (biporous ambulacrals present) within invaginated parts. Thence to ambitus typical "Pyrinid" plating, most intense (in part Discoidiid) in areas I and V. Similar plating continued above the ambitus into distal part of petal in area III, ? almost to petals in II and IV, but not reaching above ambitus in I and V. In areas last-named supra-ambital, non-petaloid plates are relatively high. Petals (except in III) uniformly Cidaroid in plating.

Recent: New Zealand and ? Madagascar.

3. THE AFFINITIES OF *APATOPYGUS*.

The entire facies of the test of *Apatopygus* agrees very closely with that of *Nucleolites*, and is superficially almost identical with that of *Trematopygus*. The large size of the peristome, and the marked disparity in length of the petals are obvious features that distinguish it from the former, while the directly transverse elongation of the peristome runs counter to the diagnostic character of the latter. The ambulacral structure, with which this paper is mainly concerned, clearly separates *Apatopygus* from *Nucleolites*, and approximates it to *Trematopygus*. It is needless to argue further the close relationship connecting all three genera. To my mind the original contention that "*Nucleolites*" *recens* is a latter-day survivor of the essentially Mesozoic Nucleolitoida is perfectly justified.

In respect of ambulacral structure, it is possible to recognize four types in the Nucleolitidæ (*sens. str.*), each of which can be ascribed to a more or less defined place in stratigraphical history. The Lower Oolitic type (e.g. "*Nucleolites*" *quadratus*, see Phil. Trans., vol. 209, pl. lxviii, fig. 2) had well-marked, congested petals, and strictly limited phyllodes containing many occluded plates. The Upper Oolitic type (e.g. *Nucleolites scutatus*, loc. cit., pl. lxviii, fig. 3) had less-restricted, little-congested petals, and ill-defined hypophyllodes in which occluded plates are rare, but demi-plates may occur. The Cretaceous type (*Trematopygus*, loc. cit., pl. lxviii, fig. 4) had long, many-plated, but feebly expanded petals, and a strangely diffuse, vestigial kind of hypophyllode, in which Pyrinid plating covers much of the adoral extent of the ambulacra, being least extensive in areas I and V. The fourth type is *Apatopygus*, with long but uncongested petals, and an exaggerated state of diffusion in the "hypophyllode", which shows features normal to *Trematopygus* developed to a far greater extent. The four types surely illustrate a morphogenetic sequence. While petal-characters appear to oscillate (save perhaps for steady reduction in the expansion of the petals), phyllode-development seems to show progressive (or, perhaps, regressive) modification. The plate-complexity that was concentrated into the true phyllodes of the older Nucleolitids (such as *Galeropygus* and "*Nucleolites*" *quadratus*) spread gradually away from the peristomial region until in area III of *Apatopygus* it involves the greater part of the area in triad-grouping. As far as phyllode-production is concerned, the change was catagenetic, but in respect of the complexity of the whole ambulacrum it was clearly anagenetic.

The sequence of ambulacral morphogenesis indicated above was carried out in a series of forms whose general evolution has been relatively static. Save for its ambulacral plating, *Apatopygus* would not have been out of place on a Middle Jurassic beach. Another line of descent from the *Galeropygus–Nucleolites* stock led in quite an opposite direction, and produced the *Clypeus–Pygurus* series with increasingly complex and limited phyllodes. That essentially Mesozoic group showed far more diversity in form, size, and detail than the conservative Nucleolitidæ, and paid the penalty of over-exuberance by extinction in the Cretaceous period. The two Nucleolitoid series thus provide clear illustration of the principles of evolution already familiar in many phyla. In comparison with Brachiopoda, *Apatopygus* may be said to bear a similar relation to *Galeropygus* to that borne by *Lingula* to *Lingulella*; while *Pygurus* would agree more with *Spirifer*. The persistent *Nautilus* and the extinct "*Ammonites*" have comparable histories.

The ambulacra of *Apatopygus* invite comparison with those of the Echinonëidæ. Save for the presence of petals and "biporous" orad ambulacrals, *A. recens* has typical Pyrinid ambulacral plating, almost perfect as far as it extends. In area I (Pl. VII, Fig. 1) there occur three Discoidiid triad-groups (similar plates appear in *Trematopygus*), so that the correspondence with Holectypoid structures is emphasized. It seems quite inconceivable that any phyletic link can connect *Apatopygus* with *Pyrina* or any other late Holectypoid; so that the appearance of Pyrinid plating in the recent form must be ascribed to parallel development.

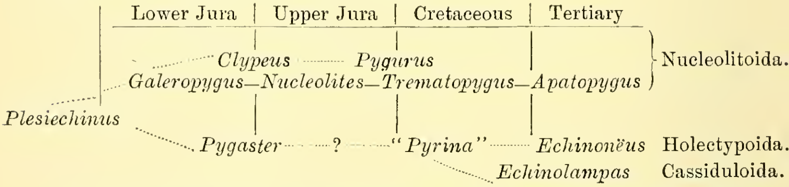
If orthogenesis supplies an explanation of this coincidence, the separable qualities of the components of "individuals" is strikingly illustrated. The ambulacra of *Apatopygus* have come to conform to the Holectypoid standard in essentials (albeit by a non-Holectypoid route); while other coronal structures have followed quite different lines of development. Further, the appearance of Pyrinid plating in the last of the Nucleolitoida seems to give support to the belief that that stock branched from the Holectypoid series (though early) rather than arose independently. That extensive triad-grouping or combination after this pattern appeared in Lower Cretaceous times in the Echinina, Echinonëidæ, Lanieriidæ, and Nucleolitidæ, is a coincidence explicable only on the assumption that morphogenesis may be not merely parallel in otherwise divergent stocks but proceeds at the same rate. Hence come "modes" or "fashions" prevalent in ultimately homogenetic series—sources of convenience to the stratigrapher and confusion to the systematist.

4. THE AFFINITIES OF *ECHINOLAMPAS*.

H. L. Clark (*Hawaiian and other Pacific Echini*, p. 143), commenting on my suggestion that the "Nucleolitidæ" (i.e. the Cassiduloidea of Sladen and Asternata of Gregory) may be diphyletic, states that "the recent species seem to form a very homogeneous group"; but he admits that "a more natural grouping in accordance with some of [my] suggestions" may prove possible. The earlier sections of this paper seem to me to show that *Apatopygus*, at least, is a very distinct type from the *Oligopodia–Rhynchopygus–Echinolampas* series of recent Cassiduloids. *Apatopygus* has definitely dissimilar petaloid pores—those of the Cassiduloida are similar and normally conjugate. I have no knowledge of any other living genus that can be associated with *Apatopygus* in the Nucleolitoida, and so agree with Clark as to the apparent homogeneity of his Nucleolitidæ with this single exception.

In several of the papers in this series, and especially in my recent memoir on ambulacra (Phil. Trans.), I have argued that the *Echinolampas*-series (which I call Cassiduloida *sens. str.*) are sequentially related to the early Echinonëidæ much as the Clypeastroida are to the Discoidiidæ. In the almost complete absence of knowledge of post-larval changes in recent Echinoids (zoologists, please note!), my arguments have necessarily been somewhat hypothetical or based on unverified assumptions. But in the section of Agassiz' Revision "On the young stages of Echini" (Part IV), p. 741, and in the plate (xvi) illustrative of the particular paragraph, something approaching ontogenetic proof of my contention appears. Agassiz says: "The development of *Echinolampas* has thrown unexpected light upon the affinities of the toothless Galerites and of the Cassidulidæ. It shows conclusively that *Echinonëus* is only a permanent embryonic stage of *Echinolampas*, thus becoming allied to the Cassidulidæ, and that it has nothing in common with the Galerites as I would limit them, confining them entirely to the group provided with teeth." These sentences were written long before Agassiz was able to record the presence of a vestigial lantern in young *Echinonëus*—in the light of that discovery the genus has almost everything "in common with the" Holectypoida. Study of Agassiz' drawings (pl. xvi, figs. 1–3) shows that *Echinolampas depressa*, when 4 mm. in diameter, is more like a *Conulus* or "*Globator*" than an *Echinonëus* in general facies, but has the tuberculation of a *Discoidea*. At a later stage, 12·7 mm. in diameter (tab. cit., figs. 8–10, here partly adapted, Pl. VII, Fig. 5), the test takes on a more depressed and elongate form, and the tuberculation becomes amplified in the hour-glass pattern characteristic of *Conulus*. (In *E. sternopetala* Ag. & Clark, "*Conulus*-tuberculation" seems persistent even in the adult.) It is in the ambulacra, however, that the young *Echinolampas* exhibits the most remarkable qualities. Agassiz says of these (l.c., p. 742), "each plate . . . carries a single primary tubercle . . . The pores are arranged . . . three or four for each plate." His enlarged drawings (here Pl. VII, Fig. 5) show that "each plate" is really a triad-group. No indication appears as to the relations of the components of the groups, but that they are not all primaries seems probable from the nature of the perradial suture. In view of Agassiz' previously quoted remark, it is reasonable to assume that the triad-groups are Pyrinid in character, like those of *Echinonëus*. Such triadic structure is persistent in *Amblypygus* (otherwise very nearly akin to *Echinolampas*), but it is *not* retained in adults of *Echinolampas* itself. Its presence in early ontogeny must surely be vestigial. In consequence the descent of the *Echinolampas*-stock from an Echinonëid (or late Holectypoid) ancestry is a conception that is now so far established that it is for those who disagree to disprove it. Stratigraphy, morphology, and now ontogeny, all point to its truth.

The ambulacral history of the Nucleolitoida and Cassiduloida (assuming the above conclusions to be accurate) shows a strange course of morphogeny. The phyletic relations of the groups, as they appear to me, can be indicated thus :—



The Nucleolitoida early acquired elaborate phyllodes, retaining simplicity in the rest of their ambulacra. During the Mesozoic era their phyllodes underwent gradual decentralization, until triad-grouping affected a large part of the areas. This tendency culminates in *Apatopygus*. On the other hand, the Holectypoida failed to develop phyllodes, but progressively spread triad-grouping over their ambulacra (e.g. "*Pyrina*"). In the Tertiary era, simplification of plating, coupled with production of well-defined phyllodes (perhaps foreshadowed in *Conulus*), characterized the Cassiduloida. The two independent trends separated rapidly in the Lower Jurassic, and then slowly converged until, in the Cretaceous, they were almost coincident. Modern Cassiduloida have reached a stage analogous with that of the precocious Clypeidæ of the Nucleolitoida. But *Apatopygus* and *Echinonëus* remain as superannuated survivors, the last of their respective orders, wearing to-day the ambulacral fashions of the Cretaceous period.

EXPLANATION OF PLATE VII.

FIG. 1.—Analysis of ambulacrum I of *Apatopygus recens*, showing Pyrinid and Discoidiid plating below the ambitus, and dissimilarity of the petaloid pores. × c. 4.

FIG. 2.—Ambulacrum III of the same specimen, similarly enlarged. Pyrinid plating extends into the distal part of the petal.

FIG. 3.—Similar analysis of ambulacrum I of *Oligopodia epigonus*. An extremely simple phyllode is succeeded by "Bothriocidaroid' plates to the petal, which shows similar pores. This is a perfectly typical Cassiduloid ambulacrum, its phyllodal simplicity being probably due to the smallness of the species. × c. 6.

FIG. 4.—Ambulacrum III of the same specimen, similarly enlarged. Both areas have exactly comparable structure, and petals of precisely the same length.

(In these four figures the ambitus is indicated by small dashes.)

FIG. 5.—Part of corona of *Echinolampas depressa* at 12·7 mm. diameter. (Modified from A Agassiz, Revision, pl. xvi, fig. 11.) The interambulacral tuberculation is roughly like that of *Conulus*, but shows greater primitiveness in the scrobicular rings of granules. The ambulacral plates are grouped (or perhaps combined) into triads. The probable course of the sutures separating the individual plates is suggested by dotted lines (not present in the original figure). The triadic grouping shown (whatever its actual form) is clearly vestigial, since it is absent in adult forms. The pore-pairs seem in process of becoming single by loss of the outer member.

The Origin of Flint.

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

MR. W. A. RICHARDSON'S paper in the December, 1919, number of this Magazine has furnished a very useful summary of the problem of the origin of flint, with some very interesting suggestions; but it cannot be allowed to pass altogether unchallenged.

It is a pity that he did not attempt to clear up the confused terminology of Chalk flint. There are, broadly, three kinds: separate flints in rows, interstratified continuous lines of flint, and contrastratified continuous lines of flint. Such terms as lines, bands, seams, layers, beds have been used indiscriminately of all three kinds. It is very desirable that some distinctive term such as "vein" should be attached to the third class, the continuous flint which at any part of its course breaks across the stratification; while "tabular" might be restricted to the interstratified continuous flint, and "row", a term which cannot suggest either vein or tabular flint, employed for lines of separate flints.

The paper is vitiated by the basic but very dubious assumption that all Chalk flint must have originated at the same time. Is it, in fact, conceivable that the interstratified rows of hollow flints can be all contemporaneous with the veins? These hollow flints practically always contain some amount of soft, loose powder, with an abnormal proportion of fossils in exceptional preservation, and a large majority have a loose spongiform nucleus. The formation and preservation of this assemblage seem to be irreconcilable with any theory but that of the flinty envelope being practically contemporaneous with the chalk; the flint veins, some of which are nearly at right angles to the stratification, seem to be irreconcilable with anything like contemporaneous origin. Mr. Richardson states that "there is no difference between the two types of flint" (i.e. the bedded and the vein flint). Chemically and optically that has presumably been established for some vein or veins; but unless cavities containing powder, or wholly enclosed fossils, are commonly found in vein flint, and vein flint commonly occurs with a thick cortex, none of which things are within my experience, the statement can hardly be accurate as it stands.

A factor of considerable importance entirely overlooked by Mr. Richardson is to be found in the marl seams so abundant in the flinty chalk. These must be more impervious than the chalk, and would naturally hold up any downward diffusing or draining solution. But the relationship between marl seams and flint rows to which this would naturally give rise on Mr. Richardson's theory, i.e. marl seams coinciding with or just below flint rows, is almost unknown in practice. On the other hand, any advocate of a precipitation after gravitation theory might well appeal to the absolute freedom from marl seams of the great thickness of Thanet Chalk, whose silica, according to him, is now aggregated into the "Three Inch" band, and might also appeal to the disseminated marl in the Lower and Middle Chalk as the reason why no drainage aggregation of silica took place there. Incidentally it may be observed that the soft, spongy, dark-grey flints which are so abundant at Trimingham are characteristic of the marly chalk.

It is not safe to place much reliance on Mr. Richardson's table (No. 2) of silica contents. He budgets there for no less than twenty-two layers of 3 inches or more in thickness, containing 100 per cent of silica. When it is considered that the unique "Three Inch" band is no more than a layer 3 inches thick containing 100 per cent of silica, it will be seen how misleading an estimate must be which is based on the assumed presence of twenty-two "Three Inch" bands within the zone of *M. coranguinum* in Thanet (to say nothing of an assumed 12 in. band of solid silica in the zone of *Marsupites*). He has further budgeted for thirty layers of 3 inches, containing 50 per cent of silica, and therefore each the equivalent of a tabular $1\frac{1}{2}$ inches thick. If he will construct to scale any conceivable section of a layer 3 inches thick, of which 50 per cent shall be flint, he will see at once that such things are extremely rare in the Chalk, and that there cannot possibly be thirty of them in the Kent Coast section in addition to twenty-two "Three Inch" bands.

In his Fig. 4 he shows the *mucronata* chalk of Dorset as flintless, and in the text he states that in the *mucronata* zone the flints are generally small and immature. I do not know what his authority is, but I can assure him that at Studland, at any rate, the *mucronata* chalk of Dorset is by no means flintless, but contains strong rows of massive and fully mature flints; so does the *mucronata* zone in the Isle of Wight at Alum Bay, and the *mucronata* zone of Norfolk on the Weybourn–Cromer coast, and also at Trimingham (in the white chalk).

Another point not touched on by Mr. Richardson is the frequency of horizontal uniformity in variations in the flints. Take, for instance, the flints of the upper part of the zone of *M. coranguinum* in Hants. In proportion as the *Uintacrinus*-band is approached, the white cortex encroaches on the clear interior and assumes a pink tinge, until the broken flints show nothing but pink cortex without any clear centre; and then it is time to look very closely for *Uintacrinus* if it has not already been found. Or take again the sponge-bed at Trimingham, which always has above and below it a bed of long slender flints like no others that I have seen. Such cases as these are much more suggestive of progressive formation of flints under varying conditions of the sea bottom than of simultaneous formation throughout many hundred feet of chalk in a more or less uniform set of conditions.

Mr. Richardson ignores the evidence of fossils, but there are several indications to be drawn from them. In the first place there are in the Chalk millions of specimens of *Echinocorys* perfectly filled with chalk. The only avenues by which this chalk could enter are the relatively minute apertures of the mouth and vent. It is clear that the ooze in which these shells were immersed after the animal's death must have been exceedingly fluid, practically liquid. With these chalk-filled *Echinocorys* there occur millions of *Echinocorys* perfectly filled with flint, yet having no vestige of flint on their outsides. Occasionally specimens of *Echinocorys* are found in which the interior is partly filled with chalk and partly with flint. In these cases there is always a definite boundary between the chalk and the flint. I have never seen any indication of sporadic silicification in the chalk inside an *Echinocorys*. These considerations seem irreconcilable with any metasomatic theory of the origin of the flint. In a medium so fluid as the ooze is shown to have been, nothing could have prevented it from filling those *Echinocorys* which are now silicified, except the presence of the dead body of the animal. As that decayed it must have been replaced by ooze unless the silica had already installed itself, and silica arriving at any later date would have found these *Echinocorys* completely filled with ooze. How are you going to arrange in a more or less consolidated deposit (on the uplift drainage theory a deposit hundreds of feet in thickness and almost necessarily consolidated) for the concentration on the two small apertures of a small proportion of the *Echinocorys* present in the chalk of streams of silica of exactly sufficient force, purity, continuity, and volume to displace every particle of chalk from the interior of these *Echinocorys* without the very slightest overflow of silica? The conclusion that the silica got there before the ooze had a chance seems irresistible. It is not difficult to see that the distinction between the chalk-filled *Echinocorys* and the flint-filled *Echinocorys* might be due to the former having at the death of the animal come to rest with the apex downwards and the mouth and vent exposed, so that the dead body was cleared out by animalculæ and not left to decay, while the latter came to rest with the apex upwards and the mouth and vent pressed into the ooze, so that the dead body was left to decay and provoke the deposition of silica.

Again, the possibility that the flints were formed at the surface of the ooze can be written off altogether on fossil evidence. The Chalk sea was full of encrusting animals, such as *Spondylus latus*, *Ostreæ*, *Serpulæ*, and *Porosphæræ*. I have never seen a case, and I do not know of one having been recorded of any organism being found encrusting a flint, though that must have happened freely if they had existed at the surface of the ooze. It is rather surprising that the suggestion should ever have been made, for it must be plain that as soon as a particle of flint had formed at the surface it would, owing to its specific gravity, sink out of sight at once in the practically liquid ooze. It would presumably sink to such a depth as the consolidation of the ooze, naturally increasing with depth, would admit, and might there form a nucleus for concretionary growth of a flint. All particles of flint arising at the surface of the ooze about the same time would presumably sink to about the same depth, which might quite well be below the range of a dredge, and would give rise to a row of flints roughly parallel with the surface of the ooze, i.e. pseudo-stratified. A question here suggests itself which I am unable to answer, i.e. whether the specific gravity of a solution of silica might be sufficient to produce the same result by a concentration of the silica in solution at some depth below the surface of the ooze where precipitation would occur, and the newly precipitated flints would then sink to their natural static level.

Again, it is a well-known thing that fossils of all descriptions are frequently embedded in flints. I have not made any express test, but it is my strong impression that fossils are much more abundant at the periphery of flints than at any other internal contour-line, or, indeed, in the whole of the interior. It is possible to regard these external fossils as having contributed to determining the outline of the flints by some power of attraction of the growing amorphous mass of colloid silica, and the most likely cause of such an attraction would be the presence on them of decaying animal matter, which would involve penecontemporaneous formation of the flint.

Again, as I have indicated above, the contents of hollow flints afford a strong argument for the contemporaneous or penecontemporaneous origin of these flints, at any rate.

On the whole a penecontemporaneous origin for row and tabular flints seems to present the minimum of conflict with facts, while the vein flint is obviously of some subsequent date at or after the formation of the uplift cracks which it occupies.

The Distribution of British Carboniferous Nautiloids.

By the late WHEELTON HIND, M.D., F.R.C.S., F.G.S.

WITH the exception of the Catalogue of Fossil Cephalopoda by Foord in the British Museum (Natural History) and the same author's monograph *Carboniferous Cephalopoda of Ireland*, the bibliography of this family as represented in Carboniferous time is scattered through many volumes and publications. Not one of the publications makes any attempt to define the precise horizon in the Carboniferous Series at which any one of the species occurs, or indicates its persistence in geological time.

It does not seem to be at all probable that the Nautiloids will lend themselves as zone indices, in the way in which Ammonoids do from Carboniferous to Jurassic times. On the other hand, Nautiloids are well distributed throughout the Carboniferous Series, and some species at least are confined to definite horizons. Hyatt's classification of Cephalopod genera was adopted by Foord in his monograph, and is followed in this paper.

The table of distribution of British Carboniferous Nautiloids shows that a comparatively large number of them are found in the Millstone Grit and Upper Coal-measures, while the Pendleside Series only possesses three species. The Carboniferous Limestone and the Upper Dibunophyllum beds are fairly rich, and there is an horizon very rich in them in the Upper Caninia beds of Ireland and Kniveton. Little Island, co. Cork, must contain some beds of Upper Dibunophyllum age, as demonstrated by the presence of *Cœlonautilus planotergatus*, *Stroboceras sulcatum*, *Vestinautilus crassimarginatus*.

TABLE SHOWING DISTRIBUTION OF BRITISH CARBONIFEROUS NAUTILOIDS.

COAL-MEASURES.

Temnocheilus carbonarius Foord.
tuberculatus Sow.
concavus J. de C. Sow.
Ephippioceras wildi Hind.
clitellarium J. de C. Sow.
costatum Foord.
Pleuronautilus pulcher Crick.
costatus Hind.
P. falcatus J. de C. Sow.
armatus J. de C. Sow.
rotifer Salter.
Cœlonautilus rawsoni Inglis.
Stroboceras quadratus Fleming.
Solenocheilus cyclostomus Phillips.
globosus Hind.
Cyclonautilus umbilicatus Hind.

MILLSTONE GRIT.

Temnocheilus tuberculatus Sow.
Pleuronautilus pulcher Crick.
nodosocarinatus F. Römer.
Ephippioceras bilobatum Sow.
Stroboceras sulcatum J. de C. Sow.
Solenocheilus globosum.
cyclolobum.

PENDLESIDE SERIES.

Phacoceras oxystomum Phillips.
Stroboceras quadratum Fleming.
Thrincoceras luidii Martin.

UPPER CARBONIFEROUS LIMESTONE – UPPER DIBUNOPHYLLUM ZONE.

Temnocheilus coronatus M'Coy.
derbiense Hind.
costato-coronatus M'Coy.
Pleuronautilus scarlettensis Reid.
Ephippioceras bilobatum Sow.
Stroboceras sulcatum J. de C. Sow
bisulcatum de Koninck.
Discitoceras leveilleanum de Koninck.
wrightei Foord.
Apheleceras latum Hind.
Vestinautilus crassimarginatus Foord.
Cœlonautilus planotergatus Phillips.
Coloceras bistriale M'Coy.
Thrincoceras luidii Martin.
Solenocheilus caledonicus Foord.
cyclostomus Phillips.
clausus Foord.
crassiventer de Koninck.
infundibulum de Koninck.
ingens Martin.
derbiensis Foord.

LOWER CARBONIFEROUS LIMESTONE (probably *Caninia*).

Trigonoceras paradoxicum J. de C. Sow.
Discitoceras leveilleanum de Koninck.
discors M'Coy.
costellatum M'Coy.
Apheleceras mutabile M'Coy.
hibernicum Foord & Crick.
discus Sow.
Mesochasmoceras latidorsatum M'Coy.
Diorugoceras planidorsatum Portlock.
Triboloceras formosum Foord.
Vestinautilus semiglaber Foord.
cariniferus J. de C. Sow.
crateriformis Foord.
pinguis de Koninck.
V. paucicarinatus Foord.
multicarinatus J. de C. Sow.
Cœlonautilus doohylensis Foord.
gradus Foord.
Planetoceras globatum J. de C. Sow.
Coloceras coyanum d'Orbigny.
bistriale M'Coy
Thrincoceras hyatti Foord.
hibernicum Foord.
Aipoceras compressum Foord.
Asymptoceras crassilabrum Foord
foordi Hyatt.
Solenocheilus dorsalis Phillips.
hibernicus Foord.

TEMNOCHEILUS M'Coy, 1844.

Type.—*T. coronatus* M'Coy, 1844, Syn. Carb. Foss. Ireland.

Temnocheilus coronatus M'Coy.—Upper Dibunophyllum zone. Lowick, Northumberland; Parwich and Castleton, Derbyshire; Stebden Hill, Yorkshire. Little Island, co. Cork, Ireland. Visé, Belgium.

T. tuberculatus Sow., 1821.—Dibunophyllum zone to Lower Coal-measures. Lower Coal-measures, Shibden and Halifax, Yorkshire; Sabden Shales, Rough Lee, Lancashire; Silica Quarry, Congleton Edge (= Sabden Shales), Cheshire. Closeburn, Dumfriesshire, Scotland.

T. concavus J. de C. Sow., 1840.—Coal-measures. Coalbrookdale; N. Staffs; Lancashire. S. Wales.

T. carbonarius Foord, 1891.—Coal-measures. Coalbrookdale; N. Staffs; Lancashire.

T. derbiense Hind.—Upper Dibunophyllum zone. Tissington, Derbyshire.

T. cricki Foord.—Described in the Catalogue of the Natural History Museum; from Ireland? but without any definite locality. Was ignored by Foord in his later monograph.

T. costato-coronatus M'Coy. — ? 4 Laws Limestone, Lowick, Northumberland.

T. tuberosus M'Coy —Derbyshire.

TRIGONOCERAS M'Coy, 1844.

Type.—*T. paradoxicum* J. de C. Sow., 1825, Min. Conch., vol. v, p. 81, pl. cccclvii.

Trigonoceras paradoxicum J. de C. Sow.—Carboniferous Limestone, C_1. St. Doolaghs, co. Dublin ; Clane, co. Kildare ; Rathkeale and Doohyle, co. Limerick ; Cork, Ireland. *Fide* De Koninck, Visé, Belgium.

PLEURONAUTILUS Mojsisovics.

Pleuronautilus falcatus J. de C. Sow.—Coal-measures. Rosser Veins, Glan Rymney, S. Wales ; Pennystone, Shropshire. Millstone Grit (Sabden Shales), Sale Wheel, River Ribble, Lancashire.

P. armatus J. de C. Sow.—Coal-measures. Pennystone, Shropshire.

P. costatus Hind.—Coal-measures. Below Gin Mine Coal, N. Staffs ; 705 feet above the Barnsley Coal at Brodsworth, Yorkshire.

P. pulcher Crick.—Millstone Grit to Coal-measures, Sabden Shales horizon, Horsebridge Clough, near Hebden Bridge ; 71 feet below the 4 ft. Coal, Cheadle, N. Staffs.

P. rotifer Salter.—This species is probably identical with *P. falcatus* J. de C. Sowerby. 150 yards above the Great Mine Coal, River Tame, Ashton-under-Lyme.

P. nodosocarinatus F. Romer. Range, Dibunophyllum zone to Millstone Grit.

SYN. *Nautilus nodiferus* Armstrong, Trans. Geol. Soc. Glasgow, vol. ii, pt. i, p. 74, pl i, figs. 6–7.
Pleuronautilus nodosocarinatus Foord, GEOL. MAG., 1891, p. 481, with woodcut.

Marine Band, Caton Green, Lancashire ; below Little Limestone, Smith's Grit, near Hawes, Swaledale, Yorkshire. U.L.S., Castlecary, Arden, Barrhead, Garngad Road, Gare, Westerhouse ; L.L.S., East Kilbride, Scotland.

P. scarlettensis Reid.—Top of Upper Dibunophyllum zone or base of Pendleside Series. Scarlet Quarry, Isle of Man.

EPHIPPIOCERAS Hyatt.

Type.—*E. ferratus* Cox, Coal-measures, Kentucky, U.S.A.

Ephippioceras bilobatum Sow.—Upper beds of Carboniferous Limestone to Coal-measures. The Caytongill Beds of Sawley, near Ripon, Yorkshire ; 4 Laws Limestone, Combe, Northumberland ; below the 3rd Grit, Congleton Edge, Cheshire ; Castletown Limestones, Isle of Man. Carboniferous Limestone, Closeburn, Dumfriesshire, Scotland.

E. clitellarium J. de C. Sowerby.—Coal-measures. Pennystone Bed, Shropshire ; Marine band above the Barnsley Coal, Yorkshire.

E. costatum Foord.—Coal-measures. Pennystone Bed, Shropshire ; below the Gin Mine Coal, N. Staffs ; Leicestershire.

E. wildi Hind.—Coal-measures. Above the Bullion Coal, Carreheys (near Colne), Burnley, Shere (near Littleborough), and Sholver (near Oldham), Lancashire.

STROBOCERAS Hyatt.

Type.—S. hartii Dawson, Acad. Geol., 3rd ed., p. 311, fig. 125.

Stroboceras sulcatum J. de C. Sow.—Upper Dibunophyllum zone of Carboniferous Limestone to Millstone Grit. 4 Laws Limestone, Combe, and Redesdale Ironstone, Northumberland; Millstone Grit, Cleul Quarries, and Pendleside Series, Burnsall, Yorkshire; D_2, River Ribble, and Sabden Shales, Rough Lee, Lancashire; near Kirkby Lonsdale, Westmorland; Castleton, Bradbourne, and Chrome Hill, Derbyshire; Poolvash, Isle of Man. In Scotland specimens are mixed with *S. quadratus* Flem., which is regarded as a synonym. Little Island, co. Cork; Mullaghfarry and Crosspatrick, Killala, co. Mayo; Carnteel, co. Tyrone, Ireland. Visé, Belgium.

S. crassum Foord.—Ring near Enniskillen, co. Fermanagh, Ireland.

S. bisulcatus de Koninck.—Upper Dibunophyllum zone. Swindon Quarry, near Cracoe, Yorkshire; Parwich, Irey Cliff, and Castleton, Derbyshire. Visé, Belgium.

S. quadratus Fleming.—Coal-measures; Pendleside Series; U.L.S., Scotland. Coal-measures of Shropshire (Pennystone Beds); Lowick and Redesdale Ironstone, Northumberland. Roscobie, Fife, and in neighbourhood of Glasgow, Scotland. Foynes Island, Ireland.

DISCITOCERAS Hyatt.

Type.—D. costellatum M'Coy.

Discitoceras leveilleanum de Koninck.—Castleton, Derbyshire; Scarlet Quarry, Isle of Man. Clane and Naas, co. Kildare, Ireland.

D. discors M'Coy.—Askeaton, co. Limerick.

D. wrightii Foord.—Upper Dibunophyllum horizon. Poolvash, Isle of Man. Little Island and Middleton, co. Cork, and Askeaton, co. Limerick, Ireland.

D. costellatum M'Coy.—Milicent and Clane, co. Kildare, Ireland.

PHACOCERAS Hyatt.

Type.—P. oxystomum Phillips.

Phacoceras oxystomum Phillips.—Probably base of Pendleside Limestone. Hodder Place, Lancashire; Lowick (M'Coy), Northumberland; Poolvash, Isle of Man. Florence Court, Enniskillen (Phillips), and Drumscraw, Tyrone (M'Coy), Ireland. Visé, Belgium.

P. ? rectisuturale Foord.—Co. Kildare.

APHELECERAS.

Type.—A. mutabile de Koninck.

Apheleceras mutabile M'Coy.—Upper Caninia zone. Kniveton, Derbyshire. Rathfarnham, co. Dublin, Clane and Naas, co. Kildare, Rathkeale, co. Limerick, Little Island, co. Cork, and Cregg, co. Meath, Ireland. Anseremme, Belgium.

A. hibernicum Foord & Crick.—St. Doolaghs, co. Dublin, Ireland.

A. trochlea M'Coy.—Probably C or S horizon. Kendal. Cookstown, co. Tyrone, Ireland.

A. latum Hind.—Upper Dibunophyllum zone. 4 Laws Limestone, Combe, Northumberland.

A. discus Sow.—Probably C or S horizon. Kendal.

MESOCHASMOCERAS Foord.

Mesochasmoceras latidorsatum M'Coy.—Clane, co. Kildare, and Argone South and Cragard, co. Limerick, Ireland.

DIORUGOCERAS Hyatt.

Diorugoceras planidorsatum Portlock.—Derrylorran, Tyrone, Ireland.

TRIBOLOCERAS Hyatt.

Type.—T. serratum de Koninck.

Triboloceras formosum Foord.—*Seminula* zone. From the Crinoid Bed, Slaidburn, Yorkshire. Lisbane, co. Limerick, and Garrikies, co. Kerry, Ireland.

VESTINAUTILUS de Ryckholt, 1852, emend. Hyatt.

Type.—V. koninckii d'Orbigny.

Vestinautilus semiglaber Foord.—Lisbane, co. Limerick, Ireland.

V. crassimarginatus Foord.—Upper Dibunophyllum zone. Parwich, Derbyshire. Little Island, co. Cork, Ireland.

V. cariniferus J. de C. Sowerby.—C. S_1. Thornley Quarry, near Chipping, Lancashire. Clane, co. Kildare, Enniskillen, co. Fermanagh, Rathkeale and Ardtomen, co. Limerick, Ireland.

V. crateriformis Foord.—C.-S. Clitheroe, Lancashire; Kniveton, Derbyshire. Rathkeale, co. Limerick, Ireland.

V. pinguis de Koninck.—Kniveton, Derbyshire. Cloghran and St. Doolaghs, co. Dublin, and Askeaton, co. Limerick, Ireland.

V. paucicarinatus Foord.—St. Doolaghs, co. Dublin, Clane, co. Kildare, Little Island, co. Cork, Ireland.

V. multicarinatus J. de C. Sowerby.—Kniveton, Derbyshire.

CŒLONAUTILUS Foord, emend. Hyatt.

Type.—C. planotergatus M'Coy.

Cœlonautilus planotergatus M'Coy.—Upper Dibunophyllum zone. Thorpe Cloud, Castleton, Bradbourne, and Pindale, Derbyshire; Withgill, Lancashire; 4 Laws Limestone, Combe, Redesdale, Northumberland; Elbolton, Craven, Yorkshire; Poolvash, Isle of Man. Little Island, co. Cork, and Rathkeale, co. Limerick, Ireland. Visé, Belgium.

C. rawsoni Inglis.—Lower Coal-measures. Above the Bullion Coal, Burnley, Lancashire; above the Bullion Coal, Halifax and Shebden, and Millstone Grit Series of Eccup and Marsden (Pale Hill), Yorkshire. *C. trapezoidalis* W. Jackson is a synonym.

C. doohylensis Foord.—Elbolton, Yorkshire. Doohyle, near Rathkeale, Ireland.

C. gradus Foord.—? Clane, co. Kildare, and Rathkeale and Curraghbridge, co. Limerick, Ireland.

PLANETOCERAS Hyatt.

Planetoceras globatum J. de C. Sow.—Horizon C_1. St. Doolaghs, co. Dublin, Kildare, and Doneraile, co. Cork, Ireland. A very much misunderstood fossil; few authors have correctly referred specimens to this genus.

COLOCERAS Hyatt.

Coloceras coyanum d'Orbigny.—C.-S. horizon. Kilmallock and Rathkeale, co. Limerick, and Ballyduff, co. Waterford, Ireland. De Koninck quotes the species from Visé, Belgium.

C. bistriale Phillips.—Poolvash, Isle of Man. Clane, co. Kildare, and Tourdeely, co. Limerick, Ireland. Woodmill, Dunfermline, U.L.S., Scotland. The distribution of this species requires further examination, and the Irish examples are from Lower Carboniferous beds and the British from higher only.

THRINCOCERAS Hyatt.

Thrincoceras hyatti Foord.—St. Doolaghs, co. Dublin.

T. hibernicum Foord.—Glenbane, co. Limerick.

T. luidii Martin.—Narrowdale, Staffs; and the Limestones of Pendleside horizon, Longstone, Derbyshire; Hodder, Lancashire; Elbolton, Yorkshire. Lady McLaren's Quarry, near Prestatyn, Wales.

AIPOCERAS Hyatt.

Aipoceras compressum Foord.—Horizon C. Clane, co. Kildare, Ireland.

ASYMPTOCERAS Ryckholt, 1852, emend. Hyatt, 1883–93.

Asymptoceras crassilabrum Foord.—Clane, co. Kildare.

A. foordi Hyatt.—Clane, co. Kildare, and Rathkeale, co. Limerick.

SOLENOCHEILUS Meek & Worthen, emend. Hyatt, 1883–93.

Solenocheilus Phillips.—C.-S. Salt Hill and Bellman Quarries, Clitheroe, Lancashire. St. Doolaghs, co. Dublin, Clane, co. Kildare, Rathkeale and near Askeaton, co. Limerick. Black Rock and Little Island, co. Cork, *fide* Griffiths.

S. hibernicus Foord.

SYN. *Acanthonautilus bispinosus* Foord.

Clane, co. Kildare, and ? Little Island, co. Cork.

S. clausus Foord.—Little Island, near Cork; probably D.

S. caledonicus Foord.—Elbolton, Yorkshire. Arden Quarry, Nitshill, Glasgow, and Roscobie, Fife, Scotland.

S. cyclostomus Phillips.—Millstone Grit, Horsebridge Clough, and High Green Wood at the horizon of the Sabden Shales; Crowdecote, Derbyshire. Axton, N. Wales.

S. crassiventer de Koninck.—The Little Limestone, Weardale; (var.) Castleton, Derbyshire.

S. infundibulum de Koninck.—Upper Beds of Dibunophyllum zone at Elbolton, Yorkshire; Hollington End, Derbyshire.

S. ingens Martin.—Upper beds of the Dibunophyllum zone.

SYN. *Solenocheilus pentagonalis* Phillips.

Little Limestone, Weardale, Durham; Bradbourne and near Ashford, Derbyshire; Astbury Old Quarry, Cheshire. Bathgate, Linlithgowshire, Closeburn and Kirtlebridge, Dumfriesshire, and Arden Quarry, Nitshill, Scotland.

S. derbiensis Foord.—Upper Dibunophyllum zone. Park Hill, Castleton, and Crowdecote, Derbyshire; Narrowdale, Staffs; 4 Laws Limestone, Combe, Northumberland; Poolvash, Isle of Man. I do not consider the variety named *S. derbiensis* var. *globularis* of Foord sufficiently distinct to be retained.

S. globosus Hind.—Millstone Grit, Lower Coal-measures. Caton; Sales Wheel, River Ribble; Bullion Coal, Carreheys, near Colne, Burnley Coalfield, Lancashire; the marine bed, Silica Quarry, Congleton Edge, Cheshire.

CYCLONAUTILUS Hind.

Cyclonautilus umbilicatus Hind.—Coal-measures. Roof of the Bullion Coal, Burnley.

On the Investigation of the Mechanical Constitution of Loose Arenaceous Sediments by the method of Elutriation, with special reference to the Thanet Beds of the Southern Side of the London Basin.

By HERBERT ARTHUR BAKER, M.Sc., F.G.S.

(*Continued from p. 370.*)

LEADING CHARACTERISTICS OF ELUTRIATION-CURVES OF SEDIMENTS.

WITH regard to the laws governing the transport, sorting, and deposition of sediments, much has still to be learned, but one fact emerges clearly from the mass of present data. During the process of transport by water the load undergoes selective treatment, or, in other words, is sorted. The late Dr. G. K. Gilbert, in the course of his important work on the transportation of débris by running water,[1] carried out experiments with mixtures of several grades of detrital material and found that before the slope of the stream had been definitely established (i.e. before the attainment of uniformity of conditions), and especially when low velocities were used, the current tended to sort the débris, building deposits with the coarser part and continuing to transport the finer material. This fact has a special bearing on the study of natural sediments. The state of equilibrium, or of perfect uniformity of conditions, is seldom, if ever, completely realized in nature, and even when approximately reached is not, as a rule, of long duration. Further, in general, the detrital

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[1] Gilbert, "The Transportation of Débris by Running Water": U.S. Geol. Surv. Professional Paper 86, 1914.

deposits of the geological column are the results of transport by and deposition from comparatively slow-moving currents. Deposits of torrential character are exceptional. Consequently, we should expect to find far-travelled natural sediments, which have been subjected to long-continued aqueous action before deposition, showing in a marked degree the results of selective treatment, and sediments deposited after a short career under transport showing very little evidence of sorting. The material composing arenaceous sediments deposited under marine conditions must, in general, have had an earlier history, during which it formed part of fluviatile or estuarine deposits, and in view of the greater vicissitudes experienced should show the results of selective action in a high degree. On the other hand, a deposit such as a fluviatile loam or brickearth, deposited after only a short career under transport, and not having been subjected to any special type of selective action, should show a marked absence of sorting. The expectation is verified. Fig. 3 shows, for purposes of comparison, the typical elutriation-curves yielded by fluviatile, estuarine, and marine sediments. In the case of the fluviatile deposit, its immaturity, from the point of view of its modification under aqueous action, is shown by the curve by the marked absence of a "hump" and by the very low grading factor. The marine sediment yields a curve with a pronounced "hump" and gives a much higher grading factor. The estuarine sediment is of intermediate type. Many more examples might be given to show the soundness of this generalization, but they are scarcely necessary at this point.

Mechanical Constitution of the Thanet Beds of the Southern Side of the London Basin.

The following summary of the leading features of the mechanical constitution exhibited by the Thanet Beds is based upon the results of a very large number of analyses of samples from a widespread area.

Everywhere along the southern side of the London Basin the Thanet Beds are always progressively coarser from the base upwards. A sample from the upper part of the Thanet Beds in any locality will always yield a higher Equivalent Grade factor than will another taken from a lower level. Samples taken from similar horizons in different localities do not, however (unless the localities are only a mile or two apart), yield corresponding figures. The Thanet Beds become finer in grain as we proceed both eastward and westward from the type district of West Kent. The Thanet Beds of East Kent, as shown by the sections at Pegwell Bay and Herne Bay, are the most fine-grained representatives of these deposits in the southern part of the London Basin (see Fig. 4). It is only, however, in the upper part of the beds that the transition from coarser to finer material, eastward and westward of West Kent, is steadily progressive. The lower part shows greater variation. The lower portion of the beds in the West Kent type area shows finer sediments

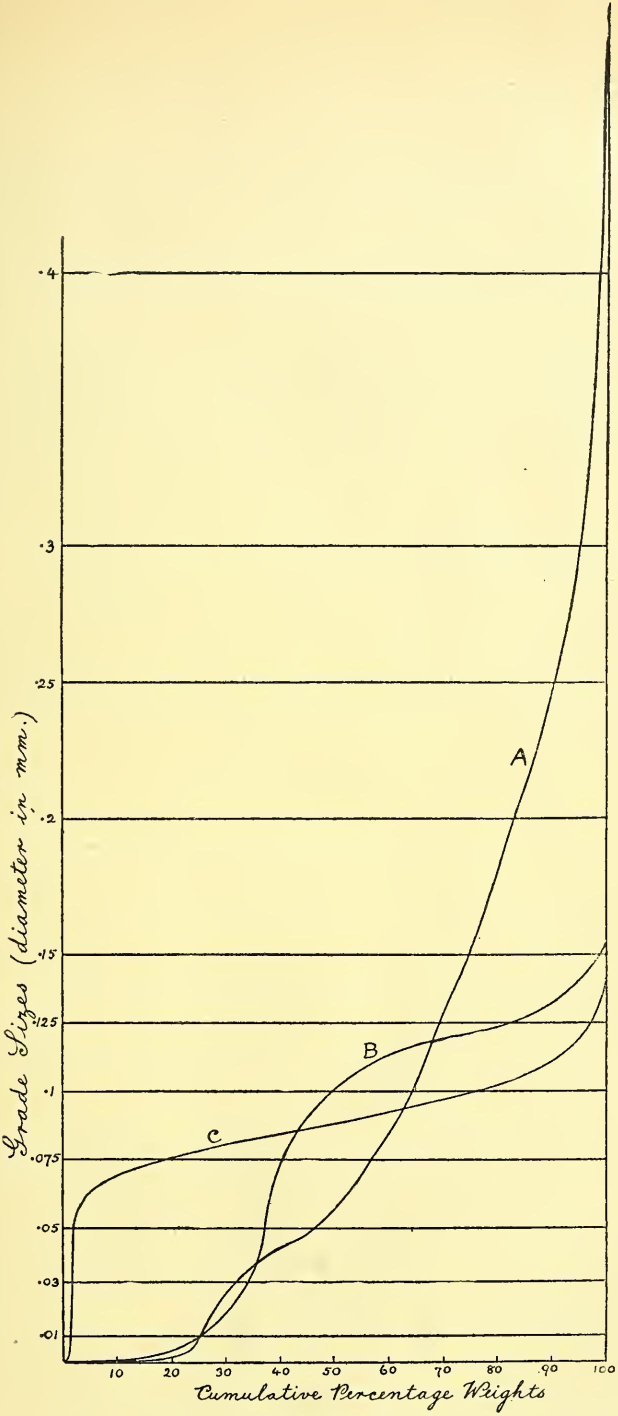

FIG. 3.—Types of elutriation curves of arenaceous sediments.

A. Fluviatile. Pleistocene Loam, Cray Valley, Foot's Cray. E = ·095 mm., G = ·140.

B. Estuarine. Woolwich Beds, Charlton; greenish loamy basement-bed. E = ·075 mm., G = ·347.

C. Marine. Oldhaven Beds, Herne Bay. E = ·088 mm., G = ·861.

than those at corresponding horizons anywhere to the west and for many miles eastward. The Lower Thanet Beds of East Kent are, however, finer than the finest sediments of the West Kent sequence. Some of the very fine, indurated, muddy sediments of Pegwell Bay proved so refractory in the laboratory that no mechanical analysis was possible. The West Kent type of Thanet Beds shows the greatest amount of variation in mechanical constitution seen in these beds anywhere in the London Basin, the Equivalent Grade factor ranging from ·059 mm. at the base of the deposit to ·146 mm. at the top. The evidence suggests that early in Thanetian times special conditions obtained in the West Kent area, whereby loamy and silty beds, not possessing in any marked degree the characteristics of marine sediments, were being deposited locally, somewhat before the definite establishment of typical marine conditions. From the fact that the lower Thanet Beds eastward and westward of West Kent (excluding the East Kent area) are fairly well-sorted sediments, giving elutriation-curves of marine type, one is tempted to hazard the conjecture that the lowest beds in West Kent may be older than these.

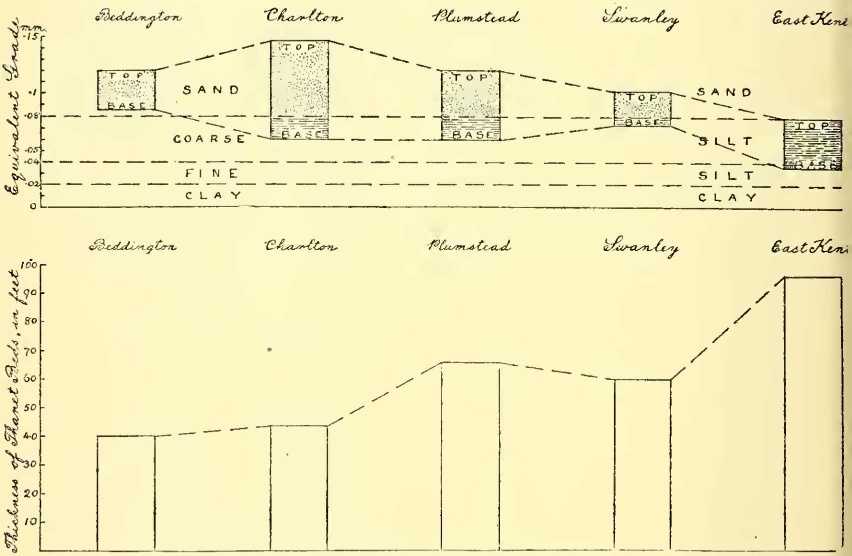

FIG. 4.—Diagram showing thickness of Thanet Beds and range in mechanical constitution, for various localities, from west to east, along the southern side of the London Basin.

Thickness of deposit, together with narrow range of variation in mechanical constitution, may be taken to indicate approximate uniformity of conditions of sedimentation, and comparative paucity of sediment with considerable lithological variation, the reverse.

Fig. 4 indicates the comparative instability of conditions of sedimentation in West Kent during the deposition of the Thanet Beds.

The diagram (Fig. 5) shows the rough, provisional classification of arenaceous sediments based upon values of Equivalent Grade and Grading Factor, in use by the writer. The value of the Equivalent Grade factor decides whether a sediment shall be classified as a sand, a silt, or a clay, the limit between sands and silts being taken at ·08 mm., and that between silts and clays at ·02 mm. The value of the Grading Factor decides whether a sediment shall be classified as a true sand or silt, or as a loam, since the characteristic of the loams is the low value of the Grading Factor. The limiting value of the Grading Factor which separates sands and silts on the one hand from loams on the other, is taken at ·6. The classification seems to answer very well.

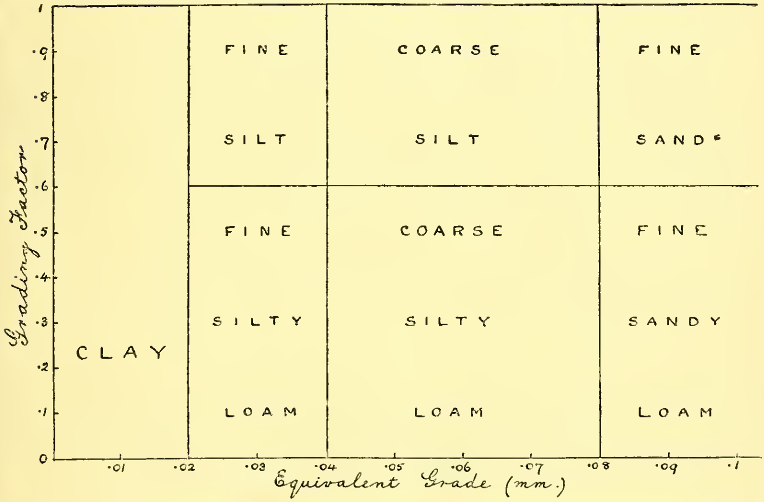

FIG. 5.—Provisional classification of the finer arenaceous sediments, based on Equivalent Grade and Grading Factor values.

Fig. 6 shows types of elutriation-curves yielded by the Thanet Beds of various localities along the southern side of the London Basin, and the table at the end of the paper gives a selection from a large number of mechanical analyses obtained by the writer.

The construction of a graph showing the relation between the Grading Factor and Equivalent Grade yields results of remarkable interest in the case of the Thanet Beds. When a series of field samples are taken from successive levels in the Thanet Beds at any one locality and mechanical analyses are carried out and the related values of Grading Factor and Equivalent Grade are plotted on a graph, it is found that the points obtained show a strong tendency to lie on a straight line. What is even more remarkable, however,

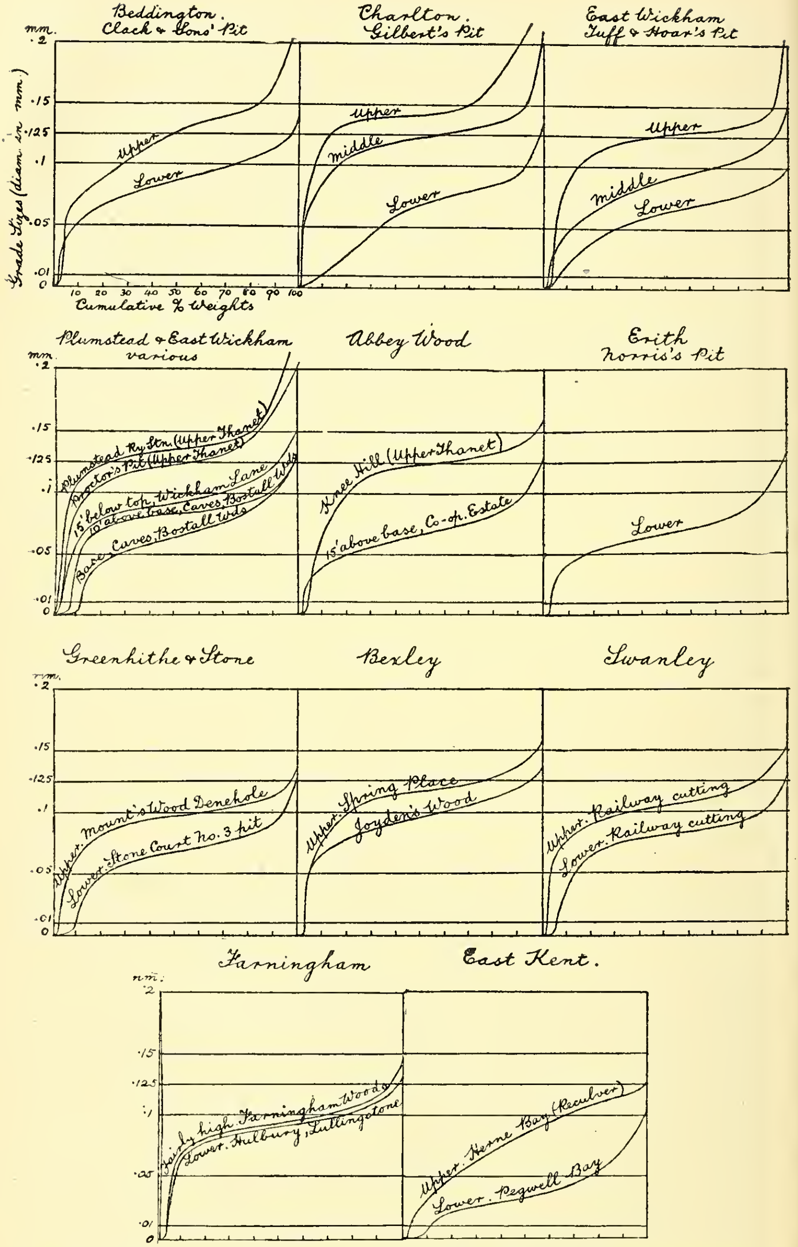

FIG. 6.—Elutriation curves (much reduced) of Thanet Beds of southern side of London Basin.

is that if this be done for a series of localities, the series of straight lines obtained show a strong tendency towards parallelism. (See Fig. 7.) This signifies that in the case of the Thanet Beds there is a tendency towards a simple linear relation between change of Equivalent Grade and change of Grading Factor. On investigating this point the writer was able to obtain the following remarkable result connecting two samples of the Thanet Beds:—

If sample 1 has Equivalent Grade E_1 and Grading Factor G_1 and sample 2 has Equivalent Grade E_2 and Grading Factor G_2,

$$\text{then } G_2 = G_1 \pm 2{\cdot}56\,(E_2 \sim E_1).$$

Take + sign when $E_2 > E_1$ and − sign when $E_2 < E_1$.

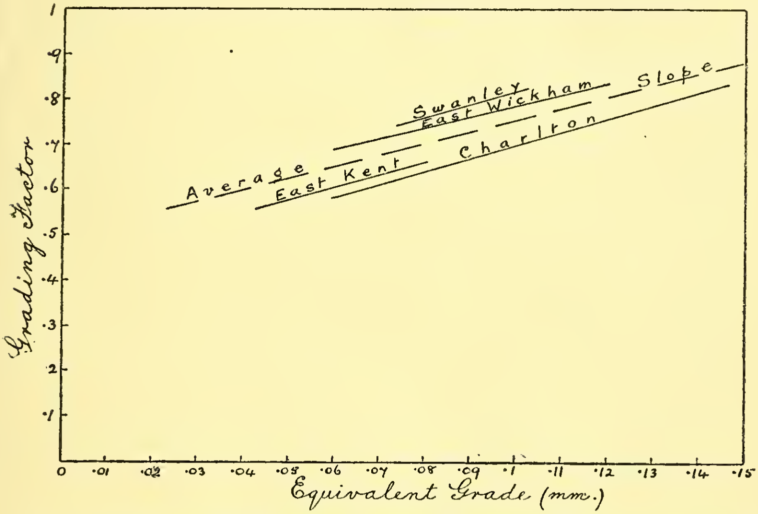

FIG. 7.—Graph showing the relation between Equivalent Grades and Grading Factors of Thanet Beds material from various localities.

This evidence of steady change in the lithological character of the sediments with concomitant change in the degree of sorting of the material signifies the establishment of conditions under which more and more highly sorted material was being deposited. The degree of sorting of a sediment is probably, in general, a cumulative effect depending upon the total vicissitudes through which it has passed, and these vicissitudes are greatest in the case of material which, originally derived from the denudation of a land-area, has passed successively through the stages of having been incorporated in fluviatile and estuarine sediments and has finally been deposited under marine conditions. In the striking feature of the Thanet Beds to which allusion has been made, we have, perhaps, the sign of the gradual and definite establishment of marine conditions.

TABLE OF MECHANICAL ANALYSES OF THANE

LOCALITY, ETC.	CLAY GRADE.	SILT GRADES.	
		Fine Silt.	Coarse Silt
	< ·01 mm.	> ·01 mm. < ·05 mm.	> ·05 mm < ·1 mm.
	% wt.	% wt.	% wt.
Beddington, Surrey. Clack & Sons' pit. Upper part of Thanet Sand	2·37	2·25	23·97
Beddington, Surrey. Clack & Sons' pit. Lower part of Thanet Sand	0·20	9·40	64·65
Charlton. Gilbert's pit. Upper Thanet Sand . .	1·45	0·67	3·97
Charlton. Gilbert's pit. Lower Thanet Beds (Blackfoot).	9·52	24·17	58·98
Plumstead Station. Upper part of Thanet Sand . .	2·57	1·50	5·28
Plumstead. Proctor's pit, east of Plumstead Common. Upper part of Thanet Sand	4·75	0·90	10·30
East Wickham. Tuff & Hoar's pit. Thanet Sand, upper part	3·72	1·58	8·48
East Wickham. Tuff & Hoar's pit. Thanet Sand, middle part	0·78	11·54	52·68
East Wickham. Tuff & Hoar's pit. Thanet Beds, lower part	2·90	26·20	70·90
East Wickham. Wickham Lane Brickfield. Thanet Sand, about 15 feet below junction with Woolwich Beds	4·28	4·92	59·66
The "Caves", East Wickham Valley. Lower Thanet Beds, about 10 feet above Bullhead Bed . . .	8·24	3·24	75·54
The "Caves", East Wickham Valley. Lower Thanet Beds, immediately above Bullhead Bed . . .	13·12	14·20	62·16
Abbey Wood. Roadside section, Knee Hill. Upper Thanet Sand, immediately below Woolwich Beds .	5·64	2·37	12·10
Abbey Wood. Co-operative Society's Estate. Thanet Beds, about 15 feet above base	2·00	18·24	72·24
Old Bexley. Spring Place, Dartford Lane. Roadside section in Upper Thanet Sand	3·42	0·92	16·05
Erith. Norris's pit. Lower part of Thanet Beds . .	1·85	14·36	74·40
Joyden's Wood, near North Cray. Thanet Sand, about middle of deposit	3·07	1·65	51·17
Farningham Woods, southern part. Thanet Sand, fairly high up in deposit	4·40	2·02	58·70
Swanley. Railway cutting between Swanley Junction and Farningham Road Station. Thanet Sand, upper part.	2·17	1·55	32·85
Swanley. Railway cutting between Swanley Junction and Farningham Road Station. Thanet Beds, lower part .	6·27	7·72	76·77
Stone. Stone Court, No. 3 pit, west of Cotton Lane. Lower part of Thanet Beds, a few feet above Chalk .	10·27	12·12	72·10
Darenth Woods. Fox and Hounds Lane. Lower Thanet Beds, just above Chalk	20·02	11·20	44·25
Hulbury, Lullingstone. Lee's pit. Thanet Beds, lower part	4·50	3·52	67·25
Bean. Mounts Wood denehole. Thanet Sand, upper part	4·25	2·52	54·75
Reculver. Cliff section. Thanet Beds, upper part .	2·77	17·97	43·82
Pegwell Bay. Cliff section. Yellow loam, indurated. Highest Thanet Beds seen, but still in lower part of deposit	9·85	59·00	28·35
Pegwell Bay. Cliff section. Thanet Beds, lowest part, just above Chalk	11·87	64·62	22·87

DS OF SOUTHERN SIDE OF LONDON BASIN.

Sand Grades.				Equivalent Grade. mm.	Grading Factor.	Remarks.
mm. 25 mm.	>·125 mm. <·15 mm.	>·15 mm. <·2 mm.	>·2mm.			
% wt.	% wt.	% wt.	% wt.			
9·99	35·47	12·36	3·59	·119	·744	Buff sand.
2·65	3·10	—	—	·085	·781	Fine yellowish-buff sand.
6·59	57·04	20·12	10·16	·146	·834	Pale sand.
6·01	1·32	—	—	·059	·581	Greyish-buff coarse silty loam.
3·98	58·50	11·80	6·37	·134	·835	Pale-yellow sand.
67·75		15·00	1·30	·120	·800	Pale-buff sand.
9·86	50·26	4·22	1·88	·120	·834	Pale-buff sand.
9·62	4·90	0·48	—	·087	·751	Fine, pale-coloured sand.
—	—	—	—	·059	·693	Greyish-buff coarse silt.
2·34	8·32	0·48	—	·086	·761	Fine, pale-buff sand.
1·26	1·72	—	—	·076	·758	Pale-buff coarse silt.
7·88	2·64	—	—	·062	·592	Pale-buff coarse silty loam.
7·00	39·67	3·22	—	·110	·788	Pale-buff sand.
6·70	0·82	—	—	·066	·736	Buff coarse silt.
4·40	22·87	2·34	—	·109	·829	Pale-buff sand.
3·02	1·37	—	—	·070	·748	Greyish-buff coarse silt.
9·16	4·95	—	—	·094	·838	Fine yellowish-buff sand.
0·30	4·58	—	—	·090	·823	Fine yellowish-buff sand.
1·15	11·77	0·51	—	·102	·824	Pale-buff sand.
3·40	0·84	—	—	·073	·746	Pale-coloured coarse silt.
4·80	0·71	—	—	·064	·669	Greyish-buff coarse silt.
0·85	1·65	2·03	—	·067	·469	Greyish-buff coarse silty loam.
3·10	1·63	—	—	·086	·798	Fine yellowish-buff sand.
6·50	1·98	—	—	·090	·801	Fine greyish-brown sand.
3·87	1·57	—	—	·080	·656	Very fine yellowish-buff sand.
2·80	—	—	—	·042	·558	Yellow, calcareous, medium silty loam.
0·64	—	—	—	·037	·555	Pale yellowish-grey fine silty loam

TABLE OF MECHANICAL ANALYSES OF THANET DS OF SOUTHERN SIDE OF LONDON BASIN.

LOCALITY, ETC.	CLAY GRADE.	SILT GRADES.		SAND GRADES.				Equivalent Grade. mm.	Grading Factor.	REMARKS.
		Fine Silt.	Coarse Silt							
	<·01 mm.	>·01 mm. <·05 mm.	>·05 mm. <·1 mm.	>·1 mm. <·125 mm.	>·125 mm. <·15 mm.	>·15 mm. <·2 mm.	>·2 mm.			
	% wt.	% wt.	% wt.	wt.	% wt.	% wt.	% wt.			
Beddington, Surrey. Clack & Sons' pit. Upper part of Thanet Sand	2·37	2·25	23·97	19·99	35·47	12·36	3·59	·119	·744	Buff sand.
Beddington, Surrey. Clack & Sons' pit. Lower part of Thanet Sand	0·20	9·40	64·65	22·65	3·10	—	—	·085	·781	Fine yellowish-buff sand.
Charlton. Gilbert's pit. Upper Thanet Sand	1·45	0·67	3·97	6·59	57·04	20·12	10·16	·146	·834	Pale sand.
Charlton. Gilbert's pit. Lower Thanet Beds (Blackfoot)	9·52	24·17	58·98	6·01	1·32	—	—	·059	·581	Greyish-buff coarse silty loam.
Plumstead Station. Upper part of Thanet Sand	2·57	1·50	5·28	3·98	58·50	11·80	6·37	·134	·835	Pale-yellow sand.
Plumstead. Proctor's pit, east of Plumstead Common. Upper part of Thanet Sand	4·75	0·90	10·30	67·75		15·00	1·30	·120	·800	Pale-buff sand.
East Wickham. Tuff & Hoar's pit. Thanet Sand, upper part	3·72	1·58	8·48	9·86	50·26	4·22	1·88	·120	·834	Pale-buff sand.
East Wickham. Tuff & Hoar's pit. Thanet Sand, middle part	0·78	11·54	52·68	9·62	4·90	0·48	—	·087	·751	Fine, pale-coloured sand.
East Wickham. Tuff & Hoar's pit. Thanet Beds, lower part	2·90	26·20	70·90	—	—	—	—	·059	·693	Greyish-buff coarse silt.
East Wickham. Wickham Lane Brickfield. Thanet Sand, about 15 feet below junction with Woolwich Beds	4·28	4·92	59·66	2·34	8·32	0·48	—	·086	·761	Fine, pale-buff sand.
The "Caves", East Wickham Valley. Lower Thanet Beds, about 10 feet above Bullhead Bed	8·24	3·24	75·54	1·26	1·72	—	—	·076	·758	Pale-buff coarse silt.
The "Caves", East Wickham Valley. Lower Thanet Beds, immediately above Bullhead Bed	13·12	14·20	62·16	·88	2·64	—	—	·062	·592	Pale-buff coarse silty loam.
Abbey Wood. Roadside section, Knee Hill. Upper Thanet Sand, immediately below Woolwich Beds	5·64	2·37	12·10	·00	39·67	3·22	—	·110	·788	Pale-buff sand.
Abbey Wood. Co-operative Society's Estate. Thanet Beds, about 15 feet above base	2·00	18·24	72·24	·70	0·82	—	—	·066	·736	Buff coarse silt.
Old Bexley. Spring Place, Dartford Lane. Roadside section in Upper Thanet Sand	3·42	0·92	16·05	4·40	22·87	2·34	—	·109	·829	Pale-buff sand.
Erith. Norris's pit. Lower part of Thanet Beds	1·85	14·36	74·40	·02	1·37	—	—	·070	·748	Greyish-buff coarse silt.
Joyden's Wood, near North Cray. Thanet Sand, about middle of deposit	3·07	1·65	51·17	·16	4·95	—	—	·094	·838	Fine yellowish-buff sand.
Farningham Woods, southern part. Thanet Sand, fairly high up in deposit	4·40	2·02	58·70	·30	4·58	—	—	·090	·823	Fine yellowish-buff sand.
Swanley. Railway cutting between Swanley Junction and Farningham Road Station. Thanet Sand, upper part.	2·17	1·55	32·85	·15	11·77	0·51	—	·102	·824	Pale-buff sand.
Swanley. Railway cutting between Swanley Junction and Farningham Road Station. Thanet Beds, lower part	6·27	7·72	76·77	·40	0·84	—	—	·073	·746	Pale-coloured coarse silt.
Stone. Stone Court, No. 3 pit, west of Cotton Lane. Lower part of Thanet Beds, a few feet above Chalk	10·27	12·12	72·10	·80	0·71	—	—	·064	·669	Greyish-buff coarse silt.
Darenth Woods. Fox and Hounds Lane. Lower Thanet Beds, just above Chalk	20·02	11·20	44·25	·85	1·65	2·03	—	·067	·469	Greyish-buff coarse silty loam.
Hulbury, Lullingstone. Lee's pit. Thanet Beds, lower part	4·50	3·52	67·25	·10	1·63	—	—	·086	·798	Fine yellowish-buff sand.
Bean. Mounts Wood denehole. Thanet Sand, upper part	4·25	2·52	54·75	·50	1·98	—	—	·090	·801	Fine greyish-brown sand.
Reculver. Cliff section. Thanet Beds, upper part	2·77	17·97	43·82	[illegible]	1·57	—	—	·080	·656	Very fine yellowish-buff sand.
Pegwell Bay. Cliff section. Yellow loam, indurated. Highest Thanet Beds seen, but still in lower part of deposit	9·85	59·00	28·35	[illegible]	—	—	—	·042	·558	Yellow, calcareous, medium silty [loam.
Pegwell Bay. Cliff section. Thanet Beds, lowest part, just above Chalk	11·87	64·62	22·[illegible]	[illegible]	—	—	—	·037	·555	Pale yellowish-grey fine silty loam

This remarkable feature in the Thanet Beds, although apparently universal in Kent, appears to be wanting farther west, in Surrey. From an examination of samples in that area the writer noted that in the upper part of the Thanet Sand an increase in the Equivalent Grade value was accompanied by a diminution in the Grading Factor. This feature was traced as far east as Charlton, where the writer found that the extreme top of the Thanet Sand, whilst giving the highest Equivalent Grade value of any Thanet Sand analysed, gave a somewhat lower Grading Factor than was expected. It seems likely that the readjustment of conditions which resulted in the succeeding Woolwich and Reading Beds being of marine type in East Kent, and of estuarine and freshwater type farther west, commenced before the deposition of the Thanet Beds had been completed.

(*To be continued.*)

REVIEWS.

William Smith : His Maps and Memoirs. By Thomas Sheppard, M.Sc., F.G.S., Curator of the Hull Museum. pp. 75–253 (the original pagination is retained), with 48 plates and other illustrations. Hull : A. Brown & Sons. 1920.

IN these days of specialization the study of the history of the rise and progress of our science receives less attention than in earlier times. In the writer's youth, for instance, a historical question on each of the subjects for the Natural Sciences Tripos at Cambridge was compulsory, but this has long ceased to be the case. This is a pity, for apart from sentimental considerations, the student will reap much advantage from a study of the difficulties with which his predecessors were confronted, and of the mistakes which they made. One of the troubles of a geologist who has to work in a country of which the geology is unknown is due to the fact that his field-work at home is learnt in an area which has been mapped in detail. By studying the life and work of Smith, he will discover how the work was done in England at a time when its geology was practically unknown.

The importance of William Smith's work is now universally recognized, but it was not always so. In Dr. Brewster's *Edinburgh Journal of Science* for April, 1831, unjust censure was passed upon the Geological Society of London for awarding the first Wollaston Medal to Smith. The action of the Society, however, was fully justified by a writer " F." in the first number of the *Monthly American Journal of Geology*, published in July, 1831, who passes high encomium upon Smith's work.

But although the importance of the work is so generally recognized, we have up to now not been in possession of a very full and detailed account of it. Professor J. Phillips's *Memoirs of William Smith, LL.D.*, appeared in 1844, but the book is now very scarce. In 1897 the late Professor Judd contributed an important paper to the Geological Magazine on " William Smith's Manuscript Maps ". Much scattered information about Smith is incorporated in Mr. Sheppard's work, and noted in the bibliography at the end of the book. But a detailed account of the labours of the " Father of English Geology " did not exist. Now, thanks to Mr. Sheppard, and to the wise policy of the Yorkshire Geological Society, from whose Proceedings the memoir is reprinted, we have it.

It is indeed fortunate that Mr. Sheppard undertook the task of writing the work. A skilled geologist, he is also fully versed in the scientific methods of the historian and bibliographer, and has evidently left no stone unturned in his efforts to trace Smith's various publications and manuscript writings, with the result that we have a worthy and almost exhaustive record of Smith's contributions to science.

After a few introductory pages the author gives some notes on work connected with geological mapping and determination of the sequence of strata prior to Smith's time. Special notice is taken of the establishment of a sequence of strata from the Chalk to the Coal-measures by the Rev. John Michell, whose claims as a geological investigator have recently been presented by Sir Archibald Geikie in a *Memoir of John Michell* published by the Cambridge University Press in 1918. Stress is also laid upon the importance of the series of County Surveys published by the Board of Agriculture in 1794 and the succeeding years, many of which indicate by colour the nature of the soils. As Mr. Sheppard remarks, "there is no doubt they were of guidance to Smith in his work."

The greater part of the book (pp. 103–80) is occupied with an account of Smith's various publications—maps, sections, books, and papers, in chronological order. This is of the highest value, and evidently entailed an enormous amount of research. It is admirably illustrated by reproductions of maps, sections, title-pages of books, tables of strata, and other material.

The fullest details are naturally reserved for those works and portions of works which deal with Yorkshire, but anyone who wishes to obtain an account of Smith's work will do so. Many of the items refer to previously unknown or forgotten publications brought to light by the author after exhaustive inquiries. The concluding parts of the book treat of Smith's MSS., notices of his work by other writers, apart from those which have been previously published, memorials to Smith, with illustrations of busts, portraits, dwelling-places, and monuments, also some appendices and a bibliography.

A few trifling misprints occur, but there is a discrepancy between the description of the plate facing p. 107, "The original Table of Strata near Bath, dictated by W. Smith, and written by the Rev. Joseph Townsend, in 1799," and the inscription on the table by Smith on p. 108, "This Table of Strata, dictated by myself, is in the handwriting of the Rev. Ben^{n}. Richardson, and was first reduced to writing at the house of the Rev. Joseph Townsend, Pulteney St., Bath, 1799. William Smith." On p. 134 the author, referring to a copy of *Strata identified by Organized Fossils*, states that in the copy in the possession of the Geological Society of London the covers are fortunately preserved, but that the date of part iii is torn off. The writer of this notice has a copy with the covers intact, and the date of part iii is, as given by the author, "September 1, 1817."

Mr. Sheppard must be heartily congratulated upon the appearance of this most important work, and thanks tendered to the Fellows of the Yorkshire Geological Society. Every geologist should read the book, and no student of the history of geological discovery, or collection of works bearing thereon, can afford to be without it. We learn from the preface to Mr. Sheppard's work that more information concerning William Smith's geological labours may be expected of him, for he states that "I have examined the collection of maps in the London Geological Society's library, which I am cataloguing at the Society's request". Perusal of the present work will make all its readers anxious for the appearance of another.

J. E. M.

The Correlation of the Quaternary Deposits of the British Isles with those of the Continent of Europe. By Charles E. P. Brooks, M.Sc., F.G.S. Smithsonian Report for 1917. pp. 277–375.

A PAPER of considerable importance to students of Pleistocene geology. It contains a summary of the chief writings upon the Pleistocene beds of various European countries, and an account of the British deposits. This summary will be found to be very useful to workers among these little-understood accumulations, and will save much reading of literature of various foreign countries. The author naturally attempts correlation of the British deposits with those of other countries. "In general the relations of the stages appear to be as follows:—

Cold period . .	Pre-Chellean.
Warm period . .	Chellean. Chelleo-Acheulian.
Cold period . .	Acheulian-Mousterian.
Warm period . .	Mousterian.
Cold period . .	Aurignacian. Solutrean. Magdalenian."

It will be seen that this classification differs in many respects from those of other writers. One feels that the time has not yet arrived for correlations over wide areas. Much more evidence must yet be obtained, but the author's paper will afford help to those occupied in obtaining that evidence.

J. E. M.

The Geology of the Country around Lichfield, including the Northern Parts of the South Staffordshire and Warwickshire Coalfields. By G. Barrow, W. Gibson, D.Sc., T. C. Cantrill, B.Sc., E. E. L. Dixon, B.Sc., and C. H. Cunnington, B.Sc.; with contributions by J. B. Hill, R.N., T. Eastwood, A.R.C.Sc., and J. Pringle. Memoirs of the Geological Survey of England and Wales. Explanation of Sheet 154. pp. vii + 302, with one plate. 1919. 9*s*. net.

THE area covered by the map which this memoir describes includes a considerable part of the North Warwickshire Coalfield, and also that part of the South Staffordshire Coalfield which lies to the north of the Bentley faults. All the old work connected with the pre-Carboniferous rocks and the productive Coal-measures is revised and brought up to date with modern mining information; interesting accounts are given of the structural features, particularly of the boundary faults, and the modern subdivisions of the red rocks of the Upper Coal-measures are described in very considerable detail. With regard to the productive Coal-measures, an interesting fact is that in the North Warwickshire field the lower coals have been found to improve towards the north, and that there is now talk of reopening old pits which were originally only sunk to the seven-feet coal higher in the series and sinking them to these lower coals. With regard to the Upper Coal-measures, a satisfactory subdivision comparable with that well known in North Staffordshire has now been established for this area. The Black-band Ironstone Group is absent, but the Etruria Marls, with their characteristic Espley rocks, are of normal type. The succeeding Halesowen Sandstone comprises two subdivisions, a lower series of sandstones and an upper one of marls with *Spirorbis* limestones; one of these, the "Index Limestone", at the base of the marls, and resting on a well-marked sandstone, is of great value in mapping and determining the depths of the coals. The Keele Beds are the normal red marls with *Spirorbis* limestones, but are overlaid by 2,000 feet of red sandstones, the Hamstead Beds, which seem to be definitely pre-Permian, and are therefore included in the Coal-measures. The accurate recognition of horizons in these rocks is a question of great importance, since the possibility or otherwise of the presence of coal at workable depths may depend entirely on the correctness of the diagnosis. As an instance of this, the country between Tamworth and the Western Boundary Fault of the North Warwickshire Coalfield may be quoted. Here rocks which were originally mapped out as Keuper Sandstone have now been proved, by the recognition of *Spirorbis* limestones associated with the peculiar rock-type known as Pellet Sandstone, to belong to the Keele series. This determination allows a fairly definite idea to be formed about the depth of the coal, whereas, on the former mapping, no estimate could have been given owing to the great unconformity existing between the Coal-measures and the Trias.

Both the coalfields described are bounded on both sides by faults of considerable downthrow. These faults show many points of interest, and not the least of these is the great width of the disturbed areas, which has been proved by the driving of exploratory headings. One of these headings, driven through the Eastern Boundary Fault of the South Staffordshire Coalfield, from the Walsall Wood Colliery's workings, proved the disturbed area to be 350 yards wide, while further south at Aldridge the belt of disturbance is 1,200 yards wide. In the first of these explorations the heading left the Shallow Coal and was driven for 75 yards through measures with broken masses of coal, for the next 73 yards it passed through grey measures much squeezed and compressed, dipping 24 degrees E.N.E.; from a distance of 148 yards to 350 yards from the starting-point the rock was all red and mottled marls, faulted and broken for the first 100 yards, and over the second 100 yards dipping more regularly at about 26 degrees. At 350 yards the heading passed through another fault, and beyond this into red marl correlated with the Keele Beds and having a still gentler dip of 16 degrees.

This and the evidence from the other boundary faults shows that they, like many other important lines of dislocation, are areas of wide shattering and step faulting, partaking more of the nature of broken folds than of clean fractures, a phenomenon which is well seen in some other coalfields.

Another point of interest about these faults is their throw in post-Triassic time, which is large in comparison with that observed elsewhere. This post-Triassic throw commonly amounts to 200 to 400 feet, while in two cases it exceeds 700 feet. The possibility of the existence of workable coal between the two coalfields is reviewed, but here the grounds on which the estimates can be made are far from secure. The unconformable relations between the Trias and the Coal-measures, the difficulty of determining the post-Triassic throw of faults, and in the southern portion the possibility of uprising of the pre-Carboniferous floor, all tend to render the formation of definite opinions a very difficult task. The one fact which stands out appears to be that the coal over a large part of this concealed coalfield must be deep, in places as much as 3,900 feet. The most promising areas appear to be in the northern part, where the Keele Beds are absent, though here sinkings would have to pass through the heavily watered Bunter. The surface of the area is in many places thickly covered with drift which must have rendered surface mapping very difficult, since in many places temporary exposures laid bare in digging for sewers and foundations are all which can be obtained. The officers of the Geological Survey have, however, been very fortunate in the co-operation of the colliery managers, and the structure of the coalfields seems now to be established on a very satisfactory basis. The map accompanying the memoir is not yet published owing to causes connected with the War.

W. H. W.

A CONTRIBUTION TO THE KNOWLEDGE OF THE MESOZOIC IGNEOUS ROCKS DEVELOPED AROUND THE TSUSHIMA BASIN, JAPAN. By TAKEO KATO. Journ. Geol. Soc. Tokio, vol. xxvii, Nos. 316 and 317, 1920.

IN these two papers a description is given of a series of igneous rocks of late Mesozoic, probably Cretaceous, age, occurring in the neighbourhood of the Straits of Tsushima. The series comprises an extrusive phase of andesites and rhyolites, more or less metamorphosed pneumatolytically by a granitic intrusion allied to the masanite of Professor Koto, the whole being subsequently penetrated by a series of acid dykes similar to the granite. It therefore affords an example of a complete normal sequence of eruptivity of Pacific type, comprising volcanic, plutonic, and hypabyssal phases, obviously derived from a common magmatic basin. The intrusives also give evidence of a certain amount of magmatic differentiation in the form of leucocratic and melanocratic facies, with aplites and pegmatites.

THE NOMENCLATURE OF PETROLOGY. By ARTHUR HOLMES, D.Sc., A.R.C.S., F.G.S. pp. 284. London: T. Murby & Co. 1920. Price 12*s.* 6*d.* net.

SOME years ago the author began to compile a card-catalogue of petrographic terms for the use of students at the Imperial College of Science; in view of the usefulness of this catalogue and in response to many suggestions he has now developed and published it in a handy form.

In the Introduction of twenty-one pages the subject of petrographic nomenclature is discussed in general terms, and with the author's remarks as to its complexity and the unnecessariness of many of the names employed by various authors we are in hearty agreement. Some petrologists really seem to have gone out of their way to coin cumbersome and jaw-breaking names, almost impossible to remember or to spell, and conveying nothing as to the actual character of the rock. In view of the Committee on Petrographic Nomenclature now sitting it would be unseemly to enter into a general discussion of the principles to be adopted in the future, but the author's temperate statement of his views may be read with profit by all petrologists.

The greater part of the book naturally consists of a glossary or dictionary of petrographic terms, including structures and properties as well as types, and including those referring to igneous, sedimentary, and metamorphic rocks. Under each heading a brief definition is given, with in many cases the name of the introducer of the word and one or more references to the literature. The list appears to be comprehensive and well selected; a few more explanations might well have been given of terms employed in economic geology, as by miners, and in the records of bores. Thus we find that most of the Scottish terms are included, while their English equivalents appear to be omitted. We confess that it is very difficult to give any precise definition of many of these words, owing to the vagueness of their use; they are, however, very puzzling to students and might well have been included with some sort of explanation, even if only a statement that they cannot be defined precisely. In this connexion we are pleased to note that the author invites suggestions from petrologists as to terms to be included in another edition.

Some useful appendices are added to the text, giving glossaries of the more common and important French and German petrological terms, lists of Latin and Greek words and prefixes, and tables of classification, the latter being largely based on the so-called degree of saturation of the rock, as suggested by Shand. Although we have noted a few trifling misprints, especially in the tables, the book seems to be remarkably free from errors, and gives evidence of a great amount of careful work and investigation of the complicated and scattered literature on the subject.

HÆMATITE AND RUTILE FORMED BY THE ACTION OF CHLORINE AT HIGH TEMPERATURES. By H. E. MERWIN and J. C. HOSTETTER. The American Mineralogist, vol. iv, No. 10, October, 1919, pp. 126 and 127.

IRON and titanium compounds were removed from the walls of a glass-pot by the action of chlorine at temperatures between 1000° and 1100° C., and deposits of hæmatite and rutile crystals of comparatively large size were formed. The hæmatite crystals were 4 mm. in diameter and the rutile crystals about 1 mm. long. The angles between the faces were measured and found to agree with those of the natural minerals. Hæmatite was shown to contain a very small proportion of FeO in solid solution, and it is suggested that this method might be used to prepare crystals with varying amounts of FeO in order to study possible variations in the angles.

W. H. W.

THE ECONOMIC GEOLOGY OF THE CENTRAL COALFIELD OF SCOTLAND, AREA VII (RUTHERGLEN, HAMILTON, AND WISHAW). Mem. Geol. Survey, Scotland. pp. vii + 140, with 6 plates and 4 figures. 1920. Price 7*s.* 6*d.* net.

SEVERAL of the memoirs of this series have already been noticed in the Magazine, and this volume follows closely on the lines of its predecessors. It deals with some of the most important mining ground in the county of Lanark with a small area in Renfrew, extending from Rutherglen to Newmains, including Cambuslang, Uddingston and Bothwell, Hamilton, Motherwell, and Wishaw. The district on the whole forms part of a deep basin, running from north-west to south-east, with its centre near Uddingston, and limited on the south-west by the Dechmont fault, with a throw of about 3,600 feet. Owing to the depth of the coals in the centre of the basin, they formed a reserve for some time, while neighbouring districts were approaching exhaustion, but even this has now been extensively worked, and it is improbable that the output will increase very much, though it may be maintained for a good many years. In 1913 the county of Lanark yielded 41 per cent of the total Scottish coal-production.

The district is almost entirely composed of Coal-measures, with a small strip of Millstone Grit in the north-east, and Lower Carboniferous rocks only to the south-west of the great Dechmont fault. There are also various superficial deposits, including pre-Glacial sands and gravels, boulder-clay, and various sands, gravels, and clays overlying it, and certain deposits of the 100 foot terrace, with peat and other recent formations. Some of these are of economic value for brick-clays, moulding and furnace sands, and other purposes.

The Geology of the Mid-Continental Oilfields. By T. O. Bosworth, D.Sc., M.A., F.G.S., F.R.G.S. pp. xii + 314. New York: The Macmillan Company. 1920.

DR. BOSWORTH has provided in this volume a most useful addition to oil-field literature. It is in the main an epitome of the voluminous and detailed work which has been carried out in this area by the United States Geological Survey and other workers. It is no light task, even if one has access to the numerous American publications, to abstract from them the specific information required, and it is this task which the author has taken in hand, and he has shown a wise discrimination in selecting from the vast amount of detail available the salient points to form a general, yet in certain respects detailed, summary of the whole.

The material is on the whole well arranged, though perhaps it might be said to suffer from over-classification. The book is divided into "parts", "chapters", and "sections", and especially in the later portion of the book there is a quite needless multiplicity of chapters, while the headlines throughout are rather reminiscent of the American press.

The work is supplemented by a very full bibliography (chap. ii), and numerous references throughout the text. Part iii gives an account of the vigorous development of the field which brought it from its modest production prior to 1903 to its present position of producing nearly one-third of the world's annual oil output, and is of especial interest at the present time when so much is being written on the world's supply of oil and America's present and future position.

The text throughout is well supplemented with plans, geological sections, tables, etc., together with a number of photographs. The author first discusses the general structure and stratigraphy of the region, and then gives in parts vi and vii a more detailed account of the local characteristics of the different fields. Parts ix and x give an account of natural gas and its relation to the distribution of oil, together with an outline of the methods employed for the recovery of "gas gasoline", a process rapidly increasing in economic importance with the ever-increasing demand for light spirit. The subject of helium is dealt with, a matter of which, owing to the activities of the censor, we heard little at the time of its discovery in commercial quantities in 1917, but one which, had the supplies of gas been mid-European instead of mid-Continental, would more than probably have been brought forcibly to our notice.

In part xii the author finishes with some "general conclusions", but we rather disagree with him that "some conclusions seem inevitable". The volume is so essentially a collection and statement of facts that part xii might well have been omitted without much loss, especially as those who will use the book presumably have, or should have, at least a general knowledge of the theories of the origin and concentration of oil and gas. That subject in itself is so extensive and important that to skim lightly over it in a page or two hardly strikes one as in keeping with the rest of the volume. As is essential to a book of this nature it is well indexed, which adds materially to its value as a work of reference.

The publishers are to be congratulated on the printing and general style of the book, though here and there exception might be taken to the proof-reading, which has been by no means perfect.

CORRESPONDENCE.

S. B. J. SKERTCHLY'S STONE IMPLEMENTS.

Sir,—I am anxious to trace the implements obtained by the late Mr. S. B. J. Skertchly from deposits of the districts around Brandon and Mildenhall, which he claimed to be of mid-Glacial age.

I should be glad if anyone in possession of any of these would kindly inform me of the fact, giving all details concerning the labels, and if possible, outline-figures of the specimens.

I trust that you will be able to help me by inserting this letter in the Geological Magazine.

John E. Marr.

Sedgwick Museum, Cambridge.
August 5, 1920.

LINGULA IN THE CHALK.

Sir,—Mr. G. W. Butler will find published records, now of some standing, in Brydone's *Stratigraphy and Fauna of the Trimmingham Chalk* (London: Dulau & Co., 1900), and in Griffith & Brydone's *Zones of the Chalk in Hants* (London: Dulau & Co., 1911). At Trimingham it has been found both in the white chalk and in the grey chalk.

R. M. Brydone.

27 Maybury Mansions,
Marylebone Street, W. 1.
July 24, 1920.

PHYSIOGRAPHIC RELATIONS OF LATERITE.

Sir,—At the end of his article in the May number of the Magazine Mr. F. Dixey gave a summary of the conditions affecting lateritization in Sierra Leone, but did not include a physiographic factor which appears to be of prime importance, namely, a late stage in a cycle of subaerial erosion, when the slow removal of rock waste from a worn-down land surface permits deep penetration of weathering with very slow movement of ground-water, and thus allows time for the various chemical reactions upon which lateritization so largely depends. The general statement of this aspect of the problem is as follows.

Conceive the changes suffered by a recently elevated region, composed mostly of such rocks as commonly underlie laterite. In the early or youthful stages of the cycle of erosion thus introduced, narrow valleys will be incised by the main rivers; the steep valley sides will exhibit bare rock or will be thinly covered with coarse rock waste which creeps rapidly down the slope to the river below, while the ground-water percolates downward more rapidly still. Laterite cannot be formed under such conditions. In a later or mature stage of the cycle, many branch valleys will also be incised, and all the valleys will be opened to slopes of a moderate degree; both strength and variety of relief will thus reach their greatest values. The valley sides will then be covered with a thicker cloak of finer rock waste, but the down-slope creep of the waste and the downward percolation of the ground-water will still be comparatively rapid; little or no laterite will be formed. In still later and much longer-enduring stages of the cycle, the valleys having been already deepened about as much as possible, the inter-valley hills will be slowly subdued to moderate or small relief, and their slopes will be reduced to gentler and gentler declivity. Thus a condition is reached in which the removal of rock waste from the general surface of the region and the movement of ground-water are very much slower than they were on the side slopes of the mature valleys. Weathering will now enter to greater and greater depths, ground-water will linger in the deep soil, and chemical changes will have time for deliberate operation. If no upheaval of the region takes place, the subdued hills may eventually be worn down to the gentle undulations of a peneplain, in the old age of the cycle, and on such a surface the processes of lateritization find their optimum.

If upheaval takes place after the peneplanation and lateritization of a region, the laterite will be quickly removed where narrow valleys are rapidly incised in the early stages of the new cycle of erosion; but the laterite will remain on the upland areas until, as maturity is approached and reached, these areas are invaded and consumed by branch valleys. The occurrence of laterite in different parts of the world gives much support to this view of its origin.

The relation of lateritization to physiographic old age thus involved is indirectly implied in Mr. Dixey's statement that "in the more hilly and mountainous parts of [Sierra Leone] . . . laterite is not nearly so well developed" (p. 214). It would be interesting to learn if the other areas, where "the solid rocks have been lateritized to a considerable depth", show worn-down surfaces of low relief. Holmes is quoted as saying that "the steep slopes of the Inselberg[1] peaks and mountain blocks [of Mozambique] are always free from deposits of lateritic constituents"; but the stage of physiographic evolution in areas where laterite occurs is not mentioned. In Fermor's review of the studies by Lacroix on laterites in Guinea, to which reference is made by Mr. Dixey in a footnote, it is said that "lateritization is everywhere intense where the slope of the ground is low enough to permit the infiltration of water and allow it to remain for a long time in contact with the rocks" (Geol. Mag., 1915, p. 128). As laterite is usually developed on deformed or crystalline rocks, the most probable means of giving them a surface of low slope is by long-continued degradation; that is, by permitting their physiographic evolution to advance to a late stage in a cycle of subaerial erosion.

The principle here involved has found application in the active search for manganese ores by members of the U.S. Geological Survey during the War; for the ore was often found to be related to some former lowland of erosion, now uplifted and more or less dissected. The nickel ore of New Caledonia is similarly situated; it occurs on uplands which, as far as I could judge, during a trip around that long island in 1914, are residuals of an uplifted and submaturely dissected peneplain (see "Metalliferous Laterite in New Caledonia": Proc. Nat. Acad. Sci., vol. iv, 1918, pp. 275–80).

W. M. Davis.

Harvard University.
May, 1920.

GLACIAL EROSION.

Sir,—I must leave it to my friend Professor Gregory to discuss in detail Professor W. M. Davis' paper on "The Glacial Erosion of Snowdon", but as the question covers a far wider area, I should like to state that I still think glacial erosion to have been, comparatively speaking, an agent of minor importance in the formation of mountain valleys. My views were expressed in the paper on "Alpine Valleys in relation to Glaciers" (Quart. Journ. Geol. Soc., 1902, p. 690), in which I refer to three others in the same journal in 1871, 1873, and 1874, which three were the fruit of some fifteen years' work. Since then I have visited the Alps (more than thirty three times in all), the Pyrenees, and several other regions, with this question always in mind, with the result that I doubt whether Professor Davis has really explored any of the regions which I describe. How many of the lateral valleys in the Alps has he ascended to their head? Has he seen the Creux de Champ, the Fer à Cheval, the Am Ende der Welt, the Croda Malcora,

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[1] Is the English language really so geographically incompetent that we must say Inselberg, Hinterland, and Thalweg instead of residual mountain, back country, and stream line?

the Rothstock Cirques, the Creux du Vent (Jura), with Gavarnie and other cirques in the Pyrenees? I may add that I saw in 1908 from a steamer two rather small but good cirques on the flank of Salina (highest point 3,156 feet) in the Lipari Islands. In these and other countries, this question has been always in my mind, so that I cannot recede from the position which I have assumed.

T. G. BONNEY.

THE CAUSES OF GLACIATION.

SIR,—In *Nature* of July 29, 1920, is an article by Dr. C. G. Abbott, of the Smithsonian Astrophysical Observatory, entitled "Solar Variation and the Weather". In it he gives an account of observations on solar radiation. These "showed on their face a variability over an extreme range of 10 per cent. . . . The sun appeared to be a variable star having . . . a fluctuation in the march of years . . . a fluctuation running its courses in a few days, weeks, or months. Both are highly irregular". The article contains comparisons of observed changes in terrestrial temperatures with observed changes in solar radiation. "It is very striking that the solar changes produce such large and prolonged temperature effects."

In speculations on the causes of Glacial Periods the suggestion has been put forward that sun-heat may have varied in past ages. Apparently there is evidence that variation is occurring even now, and that its variation is capable of producing considerable changes in temperatures on the surface of the earth.

E. HILL.

THE RECTORY, COCKFIELD,
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All Communications for the EDITOR should be addressed to

R. H. RASTALL, Esq., M.A., Christ's College, Cambridge.

All letters for Dr. H. WOODWARD, F.R.S., may be sent to

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AND

R. H. RASTALL, M.A.

OCTOBER, 1920.

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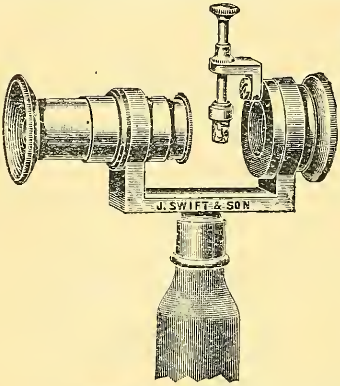
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THE
GEOLOGICAL MAGAZINE
VOLUME LVII.

No. X.—OCTOBER, 1920.

EDITORIAL NOTES.

AT this season of the year the conduct of the GEOLOGICAL MAGAZINE is beset with peculiar difficulties. Owing to the holidays our contributors are scattered far and wide, letters have to be re-addressed often more than once, and the return of proofs is unavoidably delayed. Owing to distance from libraries, also, it is often impossible for either author or editor to verify references, or to keep in touch with the latest developments of any subject. Furthermore, the supply of reviews tends to fall off. Another great drawback to the holiday season is the impossibility of collecting information of recent events of personal interest in the geological world. The Editors take this opportunity of saying that they are always grateful for news of new appointments to geological posts at home and abroad, and other similar matters of interest to the geological world. Our readers will be able to judge for themselves as to the kind of thing that is wanted. Any help in the communication of such items will be gratefully received. It may perhaps be permissible to mention here one other matter of a quasi-editorial nature. Those of our contributors who desire separate copies of their papers or other communications should make a point of sending their orders for the same to the Editor along with their corrected proof. From motives of business economy it is necessary to break up the type almost immediately after the issue is printed off, and unless orders are received before we go to press separate copies cannot be guaranteed.

* * * * * *

MESSRS. W. HEFFER & SON, LTD., Cambridge, have in the press a book entitled *Notes on Geological Map-Reading*, with forty illustrations, by Alfred Harker, LL.D., F.R.S., F.G.S., Fellow of St. John's College, and Reader in Petrology in the University of Cambridge. Probable price, 3*s*. 6*d*. net. The object of these notes is to teach the student to visualize a geological map as in three dimensions, and to show him that the questions which present themselves to the field-geologist reduce to exercises in very elementary geometry. This simplicity is gained by reckoning all slopes and dips as gradients, which enables one to dispense alike with trigonometry and with the protractor. The amount of dip, the thickness of a formation, the throw of a fault, etc., are thus measured directly upon a contoured geological map by the use of the scale alone.

ORIGINAL ARTICLES.

Preliminary Notes on the Geology of the Ningi Hills Northern Nigeria.

By Gerard W. Williams, D.S.O., M.C., M.I.M.M., F.G.S.

WITH PETROGRAPHICAL APPENDIX BY R. H. RASTALL, M.A., M.I.M.M., F.G.S.

THE country described in the following notes comprises the area lying between latitudes 10° N. and 11° 30′ N. and longitudes 8° 45′ E. and 10° E., and is situated in the northern portion of Bauchi province and the south-eastern portion of Kano province, Northern Nigeria.

The Delimi River runs diagonally through the area. This river, one of the chief feeders of Lake Chad, rises on the main hydrographic centre of Northern Nigeria. The three largest rivers that rise in the Protectorate—the Delimi, Gongola, and Kaduna—have their head-waters in a swampy, moorland plain that attains its highest elevation of approximately 5,000 feet at a point midway between Jos and Bukuru, near to the Rayfield Mines main camp. The Delimi River flows through Jos and Narraguta, and then plunges down the Narraguta Gorge below the native market. Thence northeasterly through Rafin Jaki camp, Deriko, and Bongwelli to Lemmi. Below Lemmi the river widens to 400 yards, and at Guaram it is fully 1,000 yards wide. Thence the river flows past Kategum to join the Hedaji River, and the united stream, then known as the Yo River, winds deviously eastward to Lake Chad. The headwaters above Narraguta drain the high land of the Bauchi Plateau, and as both the main stream and its upland tributaries drain from the stanniferous granite of the 'Ngell Massif the river washes are all tin-bearing. The boundaries of this massif, on its northern side, are practically continuous with the boundary of the Plateau from Rukuba to Toro. Below the plateau the Delimi has been proved tin-bearing for nearly 50 miles—as far as Lemmi. The bulk of this tin is not derived from the stanniferous granites of the plateau, but is fed to the main stream by tributaries draining the rugged group of ranges known as the Jengre Hills, of which the Buji Peak forms the highest point. The Narraguta Gorge is excavated through a series of gniesses and other ancient crystalline rocks, and the bedrock of the river as far as Lemmi is almost exclusively composed of gneisses. Below Biberi the valley widens out into a broad flood plain, which attains a width of from 10 to 12 miles at Bongwelli. From the floor of this valley rise numerous ridges and domes of granite, which decrease in number as the river flows north-east from Lemmi. From Lemmi to Lake Chad (with the exception of a few isolated granitic hummocks) the flood plain widens out on to the far-stretching plains of wind-borne sands and superficial accumulations that cover the bulk of eastern Kano and Bornu Provinces.

The traverse on which these notes were made was primarily undertaken as a prospecting tour. In consequence special attention was paid to the hilly country, as the plains, owing to their uniform covering of recent deposits, offer no exposures of the underlying rocks. Starting from the main camp of the Bongwelli Mines the route ran north through Chow and Sabon-Garri to the main camp of the Yarde Kerri Group Mines. Thence easterly to the Minna camp on the river of that name, and thence along the southern face of the Ningi Hills. Skirting the western hills of the Ningi massif the route ran over broad plains in a north-easterly direction to the massif of the Kila Hills, which rise like a smooth-walled island from the level plain. South-east of Kila the Fagam Hills were visited, but only a portion of their granite was examined. The return journey was made along the northern face of the Ningi Hills, and thence back to Sabon-Garri. From this village the return route was westerly to Rahama and back to Bukuru by rail.

From Bongwelli to Chow the basal rocks are gneissose, but exposures are few in number. The village of Chow lies at the foot of a group of granite hills, which form a singularly perfect example of platy desquamation. The domes rise sheer from the light soil, the sides at the base being usually slightly concave and the domes are perfectly rounded. The native name for this group of hills means " breasts of a young woman ", and, as is often the case in native names, the phrase is singularly appropriate.

THE SABON-GARRI GRANITE.

This granite (100)[1] is coarse-textured with felspars (perthite) up to an inch in length. The dominant ferromagnesian mineral is riebeckite. It extends over a very wide area. For convenience I have called it the Sabon-Garri granite, for it attains its largest development between that village and the Ningi Hills.

When Chow is left behind the country changes rapidly in appearance, and west and north extends a wide area of rugged granite ridges and domes. On the slopes of the valleys the thin surface soil contains large numbers of felspar crystals derived from the weathered granites.

Three miles north of Chow a very large dyke of ægirine-riebeckite-porphyry (101) forms a low ridge striking east–west, and numerous smaller dykes of similar material are visible in the granites and maintain the same general strike. Slight marginal chilling of the dyke is usually noticeable. A few miles further north a series of small dykes of devitrified rhyolite (102) are exposed in the valleys lying between the granitic domes near to Taura village.

At Tema, 5 miles south of Sabon-Garri, the typical granites are

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[1] The numbers in brackets refer to specimens now deposited in the Sedgwick Museum, Cambridge, and described in the appendix to this paper.

exposed in large, slightly convex bosses. In the bed of the Sabon-Garri River is an exposure of a coarse-textured granulitized microcline granite of highly acid characteristics (103), and immediately north is a small well-weathered exposure of highly foliated muscovite granite. The village of Sabon-Garri lies at the foot of three domes of granite (105).

From the village to Duchin Chanya Cherigi (lit. the hill that resembles a pigeon's breast—another example of apt nomenclature), the track runs in a general northerly direction, passing between numerous ridges and domes of Sabon-Garri granite. Aplitic intrusions are not uncommon. Approaching Chanya Cherigi foliation increases and in many places the granites are strongly gneissose (106).

The dark mass of Chanya Cherigi, 3,369 feet, which rises 1,000 feet above the plain level, forms a conspicuous landmark. This hill is the highest of a series of granite hills, oval in ground plan, the longer axis running due north and south. The granites in the neighbourhood show marked effects of dynamo-metamorphism. The general foliation is north and south, and the main crush zone, which extends through Gora Hill and Chanya Cherigi, is well mineralized. A well-defined lode forms the crest of these two hills, and is traceable for some 2½ to 3 miles south and north. Tin and wolfram occur in narrow, parallel, quartz-filled veins. The country rock is an altered granite containing topaz. (C.C. 4–7.) Numerous lenticular masses of aplite occur in the immediate neighbourhood. (C.C. 2-3.)

Many exceedingly rich "floaters" of tin ore (some assaying up to 50 per cent, SnO_2) occur on the slopes of the hills and in the valley below. Some of these "floaters" are exactly similar in appearance to the rich ore from the "Bushveld" tin mines (South Africa). In places the granite on the slopes of the valleys tends to weather into flat sheets, but the usual weathering is into rough blocks; many of the isolated boulders display a tendency to "mushroom" shape, due to the erosion by blown sand.

In the vicinity of Yarde Gongome, the main camp of the Yarde Kerri mines, the prevailing rocks are gneisses, and these extend northwards to Burra, at the western end of the Ningi Hills. North-east and east from Yarde Gongome the Sabon-Garri granites come in, and form a group of characteristic domes in the neighbourhood of Minna camp and near to Dogon Daji on the Minna stream.

The boundary between the Sabon-Garri granites and the gneisses is ill-defined. Contact metamorphism is entirely lacking, and masses of gneiss are frequently included in the granites. In the neighbourhood of Keffi Filani veins of pegmatite cross and recross the boundary, and the whole contact is foliated in a general equatorial direction. This foliation, which affects both granites and gneisses, was probably induced by the intrusion of the Ningi granites, the longer axis of which runs due east and west.

The dominant foliation in the country between Chow and Chanya Cherigi is distinctly meridional. Between Dogon Daji and Keffi

Filani a broad outcrop of a remarkably fresh gabbro dyke (107) exposed for a width of some 40 to 50 yards, forms a low ridge striking east and west. This was the only basic intrusion encountered during the traverse. At Keffi Filani there is a small outcrop of a somewhat granulitized, gneissose granite (108, 110), which is different in character both to the Sabon-Garri and the Ningi granites. Only two exposures were observed, one forming a few isolated knobs and the other forming a low ridge running east and west. This granite appears to be intermediate in age between the typical granites. It appears to be intrusive in the Sabon-Garri granite, but has been crushed as a result of the movements that accompanied the intrusion of the Ningi massif. No contact with the Ningi granite was observed.

THE NINGI GRANITES.

North of Keffi Filani the Ningi granites are first seen in the valley of a small stream that heads near Ka and flows south through Keffi. The well-marked contact, with chilled edges, is at this point against the old granites and gneisses. Travelling eastward towards Ningi the track skirts a low range of gneissose hills (109), with bars of harder, more siliceous rock (111), behind which rise the higher hills of the Ningi granite.

Ningi itself, lying securely behind triple walls at the head of a small valley, was formerly the chief village and fort of a Pagan tribe who conducted an extensive and profitable trade in slave raiding. The " new " granites come in about 1½ miles north of the village. The contact is clearly marked (113, 114). At the point traversed the Sabon-Garri granite forms large, flat, bare sheets (112) or slightly convex turtle backs, and the newer granite rises steeply and displays a certain horizontal jointing that resembles dry walling on a cyclopean scale. The Ningi granite (115) is a riebeckite granite, and is similar to the granite forming the Kila and Fagam massifs.

A large dyke, or series of parallel dykes of a dark-green rhyolite, starts at Ningi and runs north-easterly through the villages of Ari and Teffi. At Teffi the dyke channel is occupied by porphyries as well as rhyolites (117, 118), whilst porphyries (138) and ægirine-rhyolites (139) are exposed between Wurji and Guaram.

Between Ari and Teffi these dyke-rocks have resisted denudation more than the surrounding granites and gneisses, and stand out boldly, forming the southern wall of the hills. Passing north-east towards Wurji they form numerous isolated grassy hills and low ranges. A quartz-riebeckite syenite occurs at Teffi, lying apparently in contact with the Ningi granites and the porphyries (119, 120). At the crossing of the Delimi between Teffi and Wurji orthophyre (121) and porphyry (122) are exposed in the river bed, and exposures occur in the hills north of Wurji (123).

The syenites reappear at Guaram, where they form several low hills lying near to the town (129). The contact rocks in the north-easterly portion of the Ningi massif are syenites and porphyries, the latter predominating: small andesitic veins are found in the porphyries and in the gneisses, but never in the syenites or Ningi granites. North of the porphyries low outcrops of old granite are sometimes visible (140). Passing westward along the northern edge of the Ningi massif porphyries and rhyolites form the contact rocks as far as Lumbo, but thereafter these intrusives thin out and the contact with the old crystalline rock is obscured by superficial drifts. Near Burra contact with gneiss is well defined. The Ningi massif measures about 30 miles east and west, and averages 6 miles in width. The hills are rounded, and the highest points attain an elevation of 2,850 feet. The granite is essentially a riebeckite-biotite type, much more fine in grain than the ancient Sabon-Garri type but similar in general composition.

THE KILA GRANITES.

The Kila Hills rise abruptly from a level plain. The central peak is probably about 3,300 feet in height. Although no contact rocks are visible chilled margins (126) are to be seen towards the northern edge of the hills. The granite is essentially a riebeckite granite (124, 125). At Jugwa, near the centre of the massif, the riebeckite forms large crystals up to 2½ inches in length. The surface soil, which is deeply banked in the valleys, is obviously mostly of æolian origin. North and north-east of the hills stretch the great plains of Kategum, whose level surface of fertile wind-borne soil is unbroken by hill or ridge.

THE FAGAM GRANITES.

Travelling south-east from Kila to Guaram the route follows the main Kano–Nafada–Lake Chad road. There is only one exposure of gneiss and the soil is very deep. In a well at Yelua the water-level was 37 feet. The soil was composed of alternate layers of fine sands and marly clays, the latter probably of lacustrine origin. Near Guaram rest-house are a few low ridges of syenite (129), and south of the town numerous "floaters" of rhyolite and porphyry occur.

Like the Kila Hills the Fagam granites rise abruptly from the plains, and the deep soil is banked up the level-floored valleys and against the northern sides of the massif.

A few exposures occur about a mile from the hills: a biotite-granulite (130) forms a cluster of boulders and near by the track climbs steeply over an outcrop of quartz-syenite-porphyry (131).

The massif itself is of considerable extent, and from a hill 2,500 feet in height, which lies about 1½ miles from the stockaded village of Fagam, the granite can be seen stretching well away to the westward of Gadama. The massif is composed of a somewhat coarse-grained riebeckite granite (133). In places the riebeckite tends to form bands (134). Pegmatite veins containing large riebeckite crystals up to 2 inches in length were noted (135). Chilled margins and aplitic veins (137) were observed to the south-west of Fagam, but the actual contacts were covered with superficial accumulations.

The Intrusive Rocks of the Area.

With the exception of the gabbro dyke near Keffi Filani all the intrusives are acid in character. The gabbro, which is exceedingly fresh, is probably referable to the mid-Tertiary period of volcanic activity, of which one important focus existed near Burrin, some 140 miles to the north-west of Ningi. The characteristic intrusions in the Sabon-Garri granites are rhyolites and ægerine-riebeckite-porphyries. Rhyolites, soda-rhyolites, and porphyries form a broad belt extending from Ningi to midway between Wurji and Guaram, and, judging by " floaters ", the belt passes in an easterly direction near to the village of Duchi, a few miles south of Guaram.

Syenites occur in close proximity to the rhyolites at Teffi and at Guaram. In some cases the rhyolites are intruded into the porphyries. Dykes of quartz-felspar rock, very hard and resisting weathering well, are frequently encountered in both the gneisses and the Sabon-Garri granites. No. 111 is typical of this rock, which often forms " bars " across the hill rivers.

Rock Succession in the Area.

The following table indicates the general succession as observed during the traverse :—

Pliocene and Post-Pliocene	Æolian sands. Lacustrine sands and clays.
Tertiary (?)	Gabbro dyke.
Mesozoic	Ningi–Kila–Fagam granites (Ningi type). Ningi–Wurji rhyolites. ,, porphyries. Ningi–Guaram syenites.
?	Keffi Filani granite.
Archæan	{ Ægirine–Riebeckite porphyries. { Banded rhyolites. Riebeckite Granites—Sabon-Garri type. Gneisses and other crystalline rocks forming basal series of Northern Nigeria.

Surface Accumulations and Drainage.

North and north-east of Ningi the soil is markedly æolian in origin. During the traverse a number of test pits were sunk in the valleys of the Kela and Fagam Hills and in the drifts along the edge of these massifs. These pits almost invariably disclosed a sequence of light sands, largely wind-blown in origin, and grey or whitish clays, flocculent in water, and containing fine, wind-blown sand.[1] The clays appear to be lacustrine in origin. Near Fagam a pit sunk at the edge of the granite yielded a layer of marly clay at 12 feet (water level), which contained decomposed fragments of a shell of

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[1] Cf. *The Geography and Geology of Northern Nigeria*, pp. 215 et seq.

Limnæa (sp. ?). In the alternating sandy layers fragments of *Bulimus* (sp. ?) are sometimes found.

The valleys opening out of the hills, especially those facing north or north-east, are usually deeply filled with light, sandy soil, partly detrital and partly æolian in origin, which forms a level floor to the valley. A remarkable feature is the uniform absence of water-courses in these valleys. The rainfall, averaging 35 to 40 inches, falls mostly in a few torrential downpours during August and September. The rains pour down the bare granite catchments into the valleys, but sink through the soil and do not form water-courses. The whole country becomes waterlogged, and the few river beds that traverse the plains (mere grass-grown depressions) indicate the general direction in which the surface waters move towards the main course of the Delimi and Hedaji rivers. In the floods the Delimi overflows its low banks and spreads, many miles wide, across the planes. The country is very similar to the Cooper's Creek country of Australia, where one may perish of thirst one day and the next, 10 mile wide rivers pouring down from the Diamantina and Georgina country bear the Queensland flood waters to the lakes of South Australia. Water level in the dry season varies considerably. In the neighbourhood of the hills it varies from 6 to 12 feet, but in the plains increases to 40 feet. Further north-east the depth increases to 120 feet in Bornu province.

Parallel to the Delimi River are a series of long, narrow, deep lagoons, often surrounded by permanent swamps. Near to Guaram is a lagoon 1½ miles long, 250 yards wide, and 15 to 20 feet in depth.

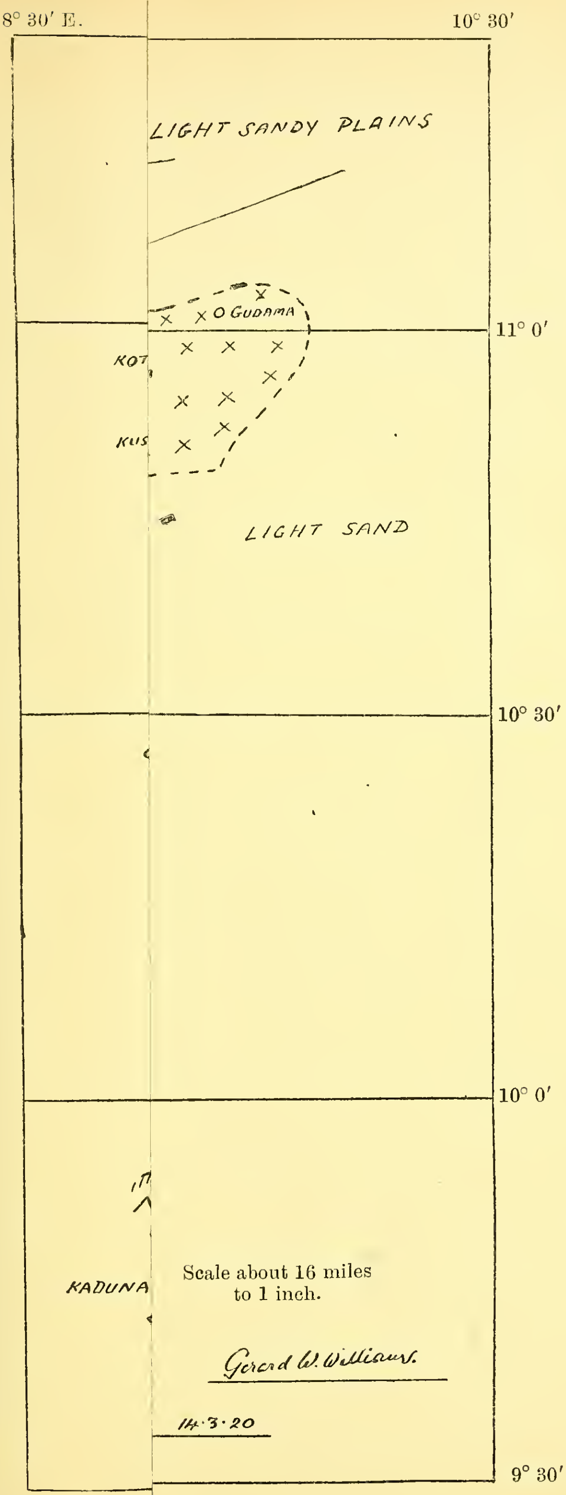
LATERITES.

The horizontally bedded layers of vesicular ironstone that are so characteristic a feature of the topography of the Bauchi Plateau and which are found throughout the country between Delimi and the Ningi Hills are not developed in the light soils east of the Kila and Fagam Hills. In the immediate vicinity of the Kila granites certain bands of sand carry concretions of ironstone, but uniform lateritic sheets are lacking.

THE OCCURRENCE OF TIN IN THE AREA.

The younger granites of the Bauchi plateau, which are similar to and probably contemporaneous with the granites of the Ningi type, are well known for the tin contained in the streams draining from them. This reconnaissance, however, definitely establishes the fact that the Archæan granites of the Sabon-Garri type are also stanniferous. From Chow to Yarde Gongome all streams that drain these granites carry more or less tin in the wash, and relatively large quantities are found in the surface soils in the vicinity of lodes such as those in the neighbourhood of Yarde Kerri.

Near to Bongwelli a pegmatite stockwerk in Sabon-Garri granite sheds a large quantity of tin into the Dada Howa creek (a Delimi



Scale about 16 miles
to 1 inch.

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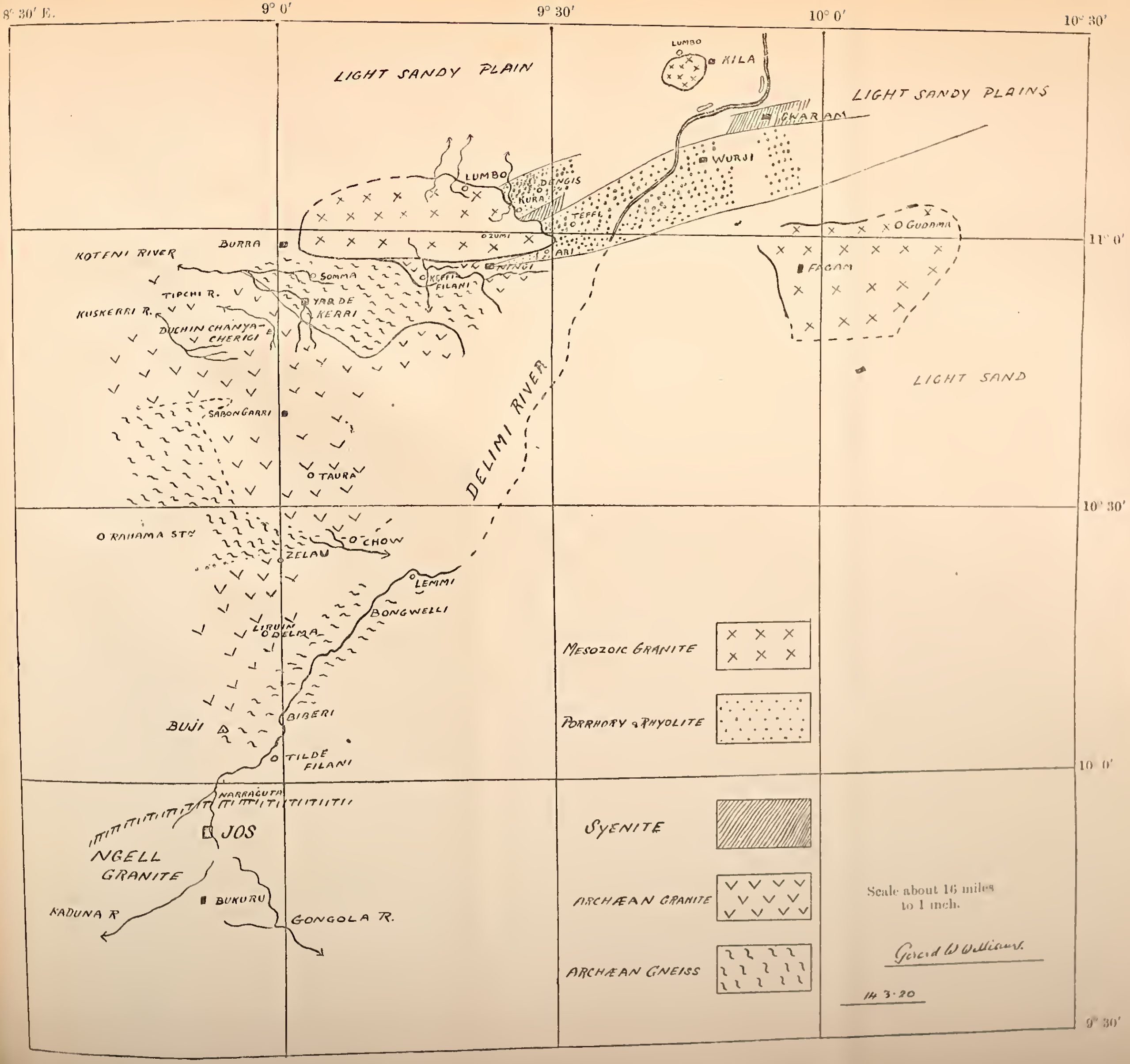

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tributary). Near to Zelau the streams are markedly stanniferous, especially those draining south and south-east to the Delimi valley. From the Jengre Hills several Delimi tributaries, especially the Buji and Zora, carry very considerable amounts of tin in the wash.

The Ningi granites yield tin, and several streams in the western end of these hills are being worked on a very small scale. Small quantities of tin, never in payable amounts, were found both in the Kila and the Pagam Hills. In these areas, however, the absence of defined watercourses militates against the economic concentration of the shed tin. No tin was ever found in streams draining only from the gneisses. For example, in the rivers of the Yarde Kerri Group Mines, the Gongome, Kogo, Kuskerri, and Tipchi River and river-flats which drain the Sabon-Garri type of granite produce tin in economic quanity, but the adjacent left fork of the Koteni, which drains a gneissose area, is absolutely barren of tin. This was also observed in the streams draining a large gneissose area between Begindi and Rahama.

If a generalization may be permitted at this stage I would say that tin is only found in granites that contain riebeckite—and this view derives further support from a consideration of the Mesozoic, tin-bearing granites of the Ropp–Monguna–Exlands areas in the southern portion of the Bauchi Plateau. On the other hand, it occurs equally in riebeckite granite of both Mesozoic and Archæan age; indeed, as far as the area traversed is concerned, it is far more abundant in the Archæan granites than in those of the Ningi type.

PETROGRAPHICAL APPENDIX.

The following notes are brief petrographical descriptions of the rock-specimens collected by Major Williams during the traverse described in the preceding paper. Most of the specimens have been sliced, but in a few instances weathering had advanced too far for this. These notes have purposely been made very short as it is hoped to obtain further specimens of the more interesting types and to publish a full account of the petrography of this area on a subsequent occasion. The nomenclature here adopted must be considered as provisional, since further information is needed as to the field-relations of some of the types collected, and no attempt has been made to institute comparisons with similar rocks elsewhere.

Description of Specimens.

100. *Riebeckite-biotite-granite.*—This is a rock of very coarse texture, with crystals of felspar up to an inch in length, quartz, and large patches of dark-coloured minerals. The largest felspars are perthite, the rest mainly albite, with a little orthoclase and microcline. Quartz is fairly abundant, both as large crystals and as rounded blebs in the felspar, with a little micropegmatite. The ferromagnesian minerals are riebeckite and deep brown biotite in

approximately equal amount. The accessories are abundant apatite, some fairly large zircons, magnetite, and allanite.

101. *Ægirine-riebeckite-porphyry.*—A porphyritic rock with phenocrysts of white felspar in a bluish-grey groundmass. The felspars are rather lath-shaped and up to 8 mm. in length. They consist of orthoclase and occasionally enclose a little quartz. The groundmass is a rather fine mosaic of orthoclase felspar, ægirine, and riebeckite, with a little quartz.

102. *Rhyolite.*—This rock possesses conspicuous flow-structures, shown by wavy bands of dark red and dark blue colours. It is much stained by iron oxide and other decomposition products, but under the microscope shows well-marked micropoecilitic structure, with a tendency to aggregation in spherulites. It is probably a devitrified glassy lava of acid composition.

103. *Microcline-granite.*—A coarse-textured granitic rock, considerably crushed and granulitized. It consists almost entirely of quartz and microcline felspar, with a very small quantity of muscovite. There is a slight tendency to micrographic structure. The rock is evidently of very acid composition, but it is a good deal decomposed, with much infiltration of secondary products along cracks and the boundaries of the minerals.

105. *Riebeckite-biotite-granite.*—A granitic rock of coarse texture, composed of quartz, microcline, subordinate plagioclase considerably decomposed, and riebeckite, with a little biotite. The accessories are iron oxide, apatite, and zircon.

106. *Granite.*—This specimen consists of quartz, decomposed orthoclase with some plagioclase near oligoclase, and patches of a green chloritic mineral, which may represent biotite. The rock has been much crushed, as is shown by the bending of cleavages and the twin-lamellæ of the plagioclase.

107. *Gabbro.*—A remarkably fresh rock, consisting of plagioclase felspar, diallage, hornblende, and a little biotite. The felspar has a refractive index higher than that of Canada balsam, and shows extinction angles up to 30 degrees. It is therefore of a basic character near labradorite. The diallage is very pale brown, with the characteristic purplish inclusions. There is also some colourless augite. The brown hornblende is often seen as a sort of graphic intergrowth with the pyroxene, all the enclosed patches commonly showing the same orientation. There is a little bright chestnut-brown biotite (lepidomelane). The only accessory mineral is a very little magnetite and no nepheline or analcime could be detected. The extraordinary freshness of this rock suggests that it is of much later date than any of the other specimens.

108 and 110. *Biotite-granite.*—Both these specimens, which are almost identical, are granulitized gneissose granites, composed of quartz, often in rounded blebs in the felspar, large microclines, and a little plagioclase. There are here and there small patches of micropegmatite. The coloured constituent is olive-brown biotite,

with accessory apatite and allanite, and a trace of purple fluorite. Although not apparently gneissose to the naked eye, the microscope shows that these rocks have been to some extent crushed and granulitized, though not so much so as the thoroughly gneissose types.

109. *Granite or gneiss.*—This appears to have been originally a gneissose granite with micropegmatite and without ferromagnesian minerals, but it is now so much decomposed that the original character of the felspar is indeterminable.

111. *Sheared gneiss.*—This rock consists of quartz and orthoclase without any original coloured minerals, but there is a little secondary epidote. It is very much sheared and granulitized.

112. *Biotite-granite.*—A rock of coarse texture and somewhat granulitized, consisting of quartz, microcline-microperthite, and brown biotite. It presents no features of particular interest.

113. *Porphyritic biotite-granite.*—The felspar of this rock is so much decomposed that its original character is uncertain, but it was probably perthite. The other minerals are quartz and brown biotite, and the structure of the groundmass is microgranitic.

114. *Biotite-granite.*—This specimen seems to show the contact between the granulitized gneissose granites of the ancient complex characterized by olive-brown biotite and the riebeckite-biotite granites of the later Ningi series. The two are, however, so inextricably intermingled along the margin that no clear description can be given. In this slice only a small trace of riebeckite can be identified, and the greater part of the specimen seems to consist of the older rock, more or less shattered by the later intrusion.

115. *Biotite-riebeckite-granite.*—A very much decomposed rock, composed of quartz and perthitic felspar in graphic intergrowth, with chestnut-brown biotite and riebeckite, and much iron oxide. There is no sign of crushing, and this rock evidently belongs to the younger series.

117. *Quartz-porphyry.*—A typical example of an acid hypabyssal rock with phenocrysts of quartz and twinned orthoclase; some phenocrysts consist of micropegmatite, and the quartzites show very good dihexagonal forms. The finely microcrystalline groundmass consists of quartz, felspar, and brown iron oxide. The quartz and felspar show micropoecilitic relations, and flow-banding is well marked. No ferromagnesian minerals remain, but some patches of yellow iron oxide may represent phenocrysts of biotite.

120. *Quartz-syenite.*—Very abundant orthoclase in large crystals with some plagioclase (albite and oligoclase), and a small amount of interstitial quartz. The ferromagnesian minerals are rather decomposed; mainly hornblende, but a little biotite was probably originally present. The hornblende is of a blue-green soda-bearing variety near to riebeckite, with strong pleochroism (greenish-blue, olive-brown, yellowish). There is a fair amount of accessory apatite and a little magnetite.

121. *Orthophyre.*—A porphyritic rock with phenocrysts of pink

felspar in a fine groundmass. It consists entirely of orthoclase and iron oxide, the latter representing some ferromagnesian mineral. The felspars of both generations are prismatic in form, and the structure of the groundmass is typically orthophyric. This is the dyke-facies of a syenitic rock.

122 and 123. *Porphyry.*—A conspicuously porphyritic rock, with phenocrysts of orthoclase in a fine groundmass of quartz, orthoclase, and red iron oxide. The orthoclase is much decomposed, and the original character of the ferromagnesian minerals is undeterminable. The groundmass is microgranitic in structure.

124. *Ægirine-riebeckite-granite.*—A remarkably fresh rock, consisting essentially of quartz, perthite, ægirine, and riebeckite. The felspar is entirely microperthite of a finely intergrown type, in idiomorphic crystals of tabular form. The quartz is interstitial and the last mineral to crystallize. Ferromagnesian minerals are not abundant; chiefly emerald-green ægirine in idiomorphic prisms with the characteristic slight pleochroism and small extinction angle; there are also a very few crystals of pale-brown or colourless augite. Deep blue riebeckite is much less abundant than ægirine; the larger crystals are nearly opaque even in a very thin slice. The only accessory seen is a little magnetite.

125. *Riebeckite-ægirine-granite.*—This rock is closely related to the last, the chief difference being the predominance of riebeckite over ægirine, and a slight tendency to micrographic structure. All the minerals show precisely similar characters and further description is unnecessary.

129. *Biotite-augite-syenite.*—A rock of fairly coarse texture and even grain, consisting of felspar, biotite, augite, and riebeckite. The felspar is chiefly perthite with a subordinate amount of plagioclase, having a refractive index lower than Canada balsam (albite). The biotite, which is very fresh, is of a deep chestnut brown colour, with very strong pleochroism; the augite is pale-green with slight pleochroism and very strong birefringence; therefore, probably ferriferous. There is a little deep blue-green riebeckite in ragged prisms, often intergrown with augite. The structure is hypidiomorphic, with a tendency to parallel arrangement in the felspars; a typical syenite.

130. *Biotite-granulite.*—An aggregate of quartz, perthite, and red-brown biotite, showing a granulitic structure. Some large crystals of felspar have a somewhat porphyritic tendency, but otherwise the structure is even-grained and granular, of the aplitic type. The most noticeable feature is the intense colour of the biotite (lepidomelane), which is quite opaque in the position of maximum absorption.

131. *Hybrid rock* (?).—Large phenocrysts of orthoclase felspar, somewhat rhombic in form and full of inclusions, in a groundmass of very variable texture, composed of quartz, perthite, orthoclase, and green hornblende. In parts the groundmass is granulitic

and micrographic, while in other parts the minerals show the relations characteristic of a dolerite. The specimen also contains a good many pebbles of quartz, with corrosion borders, obviously xenolithic, and it is probable that the whole thing is a mixture rock, composed of alkali-granitic and alkali-doleritic materials. Further material is necessary to elucidate this point.

133 and 134. *Riebeckite-granite.*—A granitic rock of coarse texture, consisting exclusively of quartz, white perthite, and riebeckite. Quartz is very abundant and shows a slight tendency to graphic intergrowth with the felspar. The riebeckite is of a deep prussian blue colour, visible even in the hand-specimen ; it forms irregular patches, and occasionally long idiomorphic prisms. The only accessory observed is a small amount of deep purple fluorspar, occasionally visible even in the hand-specimen, but chiefly microscopic.

135. *Riebeckite-pegmatite.*—A small hand specimen associated with the two foregoing, of fairly coarse pegmatitic character, consists of quartz, flesh-red felspar, and large prisms of riebeckite up to two inches in length.

137. *Biotite-aplite Vein.*—This specimen consists of a perthite-granite of fairly coarse texture penetrated by a vein of aplitic character, with red-brown biotite.

138. *Augite-porphyry.*—Phenocrysts of pink and occasionally white felspar in a matrix of quartz, felspar and augite, now represented mainly by some chloritic mineral. The large white felspars, which appear to be albite, have a border of pink orthoclase, and the pink felspars are orthoclase so far as they can be determined : all are considerably decomposed. The groundmass is rather fine in texture, mainly orthoclase in irregular patches with pale green augite, chlorite and a little interstitial quartz, with some opaque iron-ore. This is the hypabyssal facies of a syenitic rock, with dominant potash.

139. *Ægirine-rhyolite.*—A greyish-green rock with very conspicuous flow-structure. It contains phenocrysts of quartz and perthite felspar in a groundmass of variable texture : some bands show a microgranitic structure, while others are finely microcrystalline. The minerals of the groundmass are quartz, felspar and ægirine, the latter in small shapeless or elongated grains, with an occasional larger prismatic form : the latter occur chiefly in the coarser bands. No other ferromagnesian minerals were observed.

140. *Graphic Granite.*—The minerals of this specimen are too much decomposed for certain determination. The felspar was probably orthoclase, since no indications of polysynthetic twinning could be seen. The only noticeable feature is the well-marked micrographic structure. There are a few large zircons and a little magnetite.

C.C. 3. *Biotite-granulite.*—A rock of granulitic or aplitic structure, consisting of quartz, microcline, orthoclase, and biotite.

The quartz and felspar are in some parts micrographically intergrown, while elsewhere the structure is granular-hypidiomorphic. The biotite is olive-brown and contains inclusions of allanite with pleochroic halves. This rock appears to be very similar to Nos. 108 and 110, though finer in texture.

C.C. 4. *Topaz-rock.*—This is a specimen of the aplitic rock associated with the tin-tungsten lodes: the actual slice was taken about 1 inch from the edge of a narrow lode of this kind. It consists of quartz, some highly decomposed material representing felspar, topaz, and red and black patches which probably include both iron oxide and wolfram. Quartz, which is very full of bubbles, is the most abundant mineral, followed by topaz. Most of the felspar has completely disappeared, and the specimen is an excellent example of a pneumatolytic topazified rock, allied to greisen in its manner of formation. Cassiterite could not be identified in the slice, though the lodes carry tin.

CONCLUSIONS.

The microscopic examination of these specimens confirms in all respects the results arrived at by Major Williams from his field observations. It is quite clear that there are here three types of igneous rock, as follows:—

1. Highly granulitized and crushed granitic gneisses, rich in microcline, with little or no ferromagnesian mineral (103, 109, 111, 112). These appear to be essentially potash granites.

2. Slightly crushed granites intrusive into the above, specially characterized by perthite, riebeckite, and ægirine, and therefore characteristically rich in soda (100, 105, 106, 113, 115). Numbers 108, 110, C.C. 3, C.C. 4 probably belong here. This series contains accessory allanite.

3. A still later series of soda granites, quite free from kataklastic structures, with perthite, riebeckite, and ægirine (124, 125, 133, 134, 135). These are accompanied by smaller intrusions of syenite and a considerable variety of syenite dykes and other small intrusions (101, 102, 120, 121, 122, 123, 129, 138, 139). This series is believed to be of Mesozoic age.

The only basic rock observed (107) is so different from the rest, and so conspicuously fresh and unaltered that it may with some confidence be referred to the Tertiary period.

The first group as here defined corresponds to the older granites of Falconer's classification.[1] The second group are believed to be also of Archæan age, although they appear to have undergone considerably less dynamic metamorphism. It is as yet impossible to state whether any of the hypabyssal types belong to this group. The third group, which may be described collectively as the Ningi series, has evidently undergone much more differentiation, since it includes a large number of dykes and small masses of syenitic

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[1] *The Geology and Geography of Northern Nigeria,* London, 1911, chap. iii.

FIG. 1.—The great diamond mine at Sopa, near Diamantina, Minas Geraes, Brazil. Note the excavation in the soft sericitic schist. The surrounding country is hard quartzite.

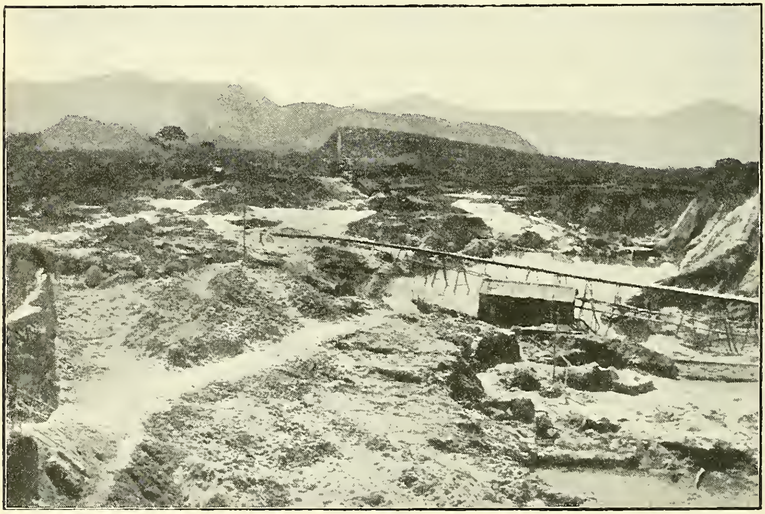

FIG. 2.—The great diamond mine at Boa Vista, near Diamantina, Minas Geraes, Brazil. Note the fissure-like excavation of the mine. The surrounding plateau is formed of hard quartzites.

To face p. 447.]

composition, and some of the specimens here described as rhyolites show all the characteristics of lava-flows.

From the mineralogical point of view, the most interesting features of the later Archæan and Mesozoic igneous rocks is the dominance of alkaline characters. The felspar is mainly perthite, while the ferromagnesian minerals are chiefly riebeckite and ægirine; the magma was therefore rich in soda; however, no nepheline has been found in the more basic (syenitic types).

Although tin, wolfram, and topaz are abundant in the area, and fluorspar occurs locally, it is remarkable that among these specimens not a single occurrence of tourmaline has been observed. It is evident that the pneumatolytic phase was characterized by fluorine to the exclusion of boron.

The Existence of Diamond-bearing "Pipes" in Brazil.

By Robert R. Walls, M.A., B.Sc.

(PLATE VIII.)

THERE has been great controversy as to whether or not there exist in Brazil diamond-bearing "pipes" such as are found in South Africa. That something of the kind should exist seems to be pretty well acknowledged, but any evidence in support of the discovery of a "pipe" has always been very meagre. The following observations made by the writer on a few mines in the neighbourhood of Diamantina, in the state of Minas Geraes, might be of interest on this somewhat vexed question.

The writer had no practical experience whatever of diamond mines when he arrived in Brazil, and was only drawn into the subject by accident. When studying the sandstones and quartzites of the Serra do Espinhaco he found that in many places these had been "stewed up" as it were and metamorphosed into rock crystal. There was no sign of a granite or aplite intrusion in the neighbourhood, but these crystal formations all lay close to the great diamond mine at Sopa, and from the field evidence alone it seemed as if this latter must have been an igneous intrusion.

The rocks of the district are all hard quartzites, remarkable for the horizontality and regularity of their bedding. The great mine takes the form of a fissure, a mile or more in length, and seems to run down vertically through the bedded quartzites, although the actual contact was nowhere exposed. This pipe or fissure is filled with a sericitic schist crowded with small crystals and concretions of iron-ores. It is green in colour, and so soft that it can be easily broken down with wooden spades and bateas. This green earth is then washed by negro labour, and the iron-ores and diamonds are left as a heavy residue. The green earth bleaches to a white clay, and is found all down the streams mingled with quartz sand. The Sopa mine lies on the very summit of the ridge of the Serra do Espinhaco, and the streams which run down from it are diamantiferous for hundreds of miles. Many important placer mines are worked in the beds of these rivers.

The field evidence therefore—the long fissure in the quartzites and the trail of diamonds from thence to the sea—seems to indicate that this was a pipe of igneous origin and the original home of the diamonds. But the sericitic schist with its concretions and crystals of iron-ores which fills the fissure differs considerably from the Kimberlite of the South African mines. Unfortunately also Brazilian geologists of considerable standing have contended for so long that there were no pipes in Brazil equivalent to the Kimberlite pipes of South Africa that to establish the fact of their existence will require much more evidence on the general geology of the district.

Besides Sopa two other mines on the summit of the Serra do Espinhaco exhibit the phenomena of pipes. One of these lies at Boa Vista, some 20 or 30 miles south-east of Sopa. The writer visited this mine and found it being worked under the direction of Mr. Draper, an engineer who had had considerable experience in the pipes of South Africa and who recognized this as an igneous pipe, though highly metamorphosed. The aspects of these two mines are shown on the accompanying plate, where they are seen as long fissures surrounded by the hard horizontally bedded quartzites. The third mine at Sao Joao de Chapada lies about 15 miles north of Sopa, and though the writer did not visit it he was assured by miners who had worked there that it was exactly similar to the mine at Sopa. These three mines occur in separate and distinct outcrops of sericitic schist, and the intervening country is covered entirely by the quartzites. These quartzites appear to be of considerable thickness in the neighbourhood of Diamantina and to lie directly on the crystalline complex.

The geology of the diamond region of Bahia farther north on the Serra do Espinhaco is now pretty well known owing to the researches of Derby, Branner, and Crandell. The following strata counting from below upwards have been mapped there :—

9. Recent formations.
8. Salitre Series.
7. Estancia Series.
6. Lavras Series.
5. Paraguassu Series.
4. Jacuipe Flints and Caboclo Shales.
3. Tombador Series
2. Jacobina Series.
1. Crystalline Complex.

With the exception of the first of these they are all sedimentary deposits. The Lavras series is the one which contains the principal diamond mines, and the inference is, therefore, that the diamonds have been obtained from the disintegration of older rocks. This only leaves us five series of strata with their contemporaneous igneous intrusions. Again the general evidence seems to point to the fact that the drainage has always been as at present from the south or

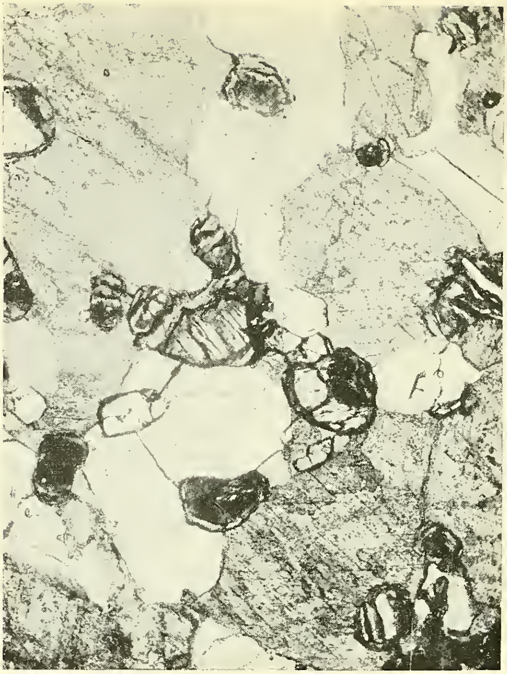

FIG. 1.

FIG. 2.

from what the writer calls the high plateau of south-east Brazil. This would indicate that the diamonds now found in the Lavras series in Bahia had their origin in an igneous rock somewhere in the high plateau to the south. Carrying the inference still further we might assume that the sudden appearance of the diamonds in the Lavras series and their absence from earlier strata (which seems to be the summary of the evidence of Derby, Branner, and Crandell) would indicate the formation of the diamond in an igneous rock of later Paraguassu age. The weathering of an intrusive rock of this period would then give rise to the diamond-bearing Lavras series.

The quartzites of the Diamantina region in Minas Geraes are supposed to be contemporaneous with the Jacobina series of Bahia. The overlying strata have been removed by denudation. If the assumed pipes of Sopa, Boa Vista, and elsewhere are of late Paraguassu age there must have been considerable erosion with removal of their diamond contents. This would certainly account for the rich deposits in sedimentary rocks lying to the north. The present sections are the deep-seated remnants of pipes which no doubt towered above their present sites for many hundreds or even thousands of feet.

All the above-mentioned rocks, with the exception of group 9, are of early Palæozoic age, and have been highly metamorphosed. Whether the sericitic schist of Sopa is the metamorphosed remnant of an igneous intrusion, and, if so, by what chemical process it has been so metamorphosed is a question for the geological chemist. The commercial aspect of the question, the discovery of the original home of the diamond which has scattered its wealth over such great areas of sedimentary rock in Brazil, would certainly warrant a closer investigation into the subject.

The Metamorphism of the Pre-Cambrian Dolomites of Southern Eyre Peninsula, South Australia.

By C. E. Tilley, B.Sc., A.I.C., Emmanuel College, Cambridge.

(PLATE IX.)

Introduction.

THE basement platform of Southern Eyre Peninsula consists of a series of igneous and metamorphic rocks of pre-Cambrian age. Rising from beneath the Mesozoic and Tertiary strata of the

Nullarbor plains, they may be regarded as a south-easterly prolongation of the great pre-Cambrian Shield of Western Australia. The platform is for the most part within a few hundred feet of sea-level, and large areas of the region are covered by the products of long-continued weathering of the older rocks or by siliceous deposits of late Tertiary age. The best sections for geological study are those exposed along the coastline, and in the hilly areas of Hutchison and Warrow.

The general discussion of the sequence of the pre-Cambrian in this area will be reserved for another place, and this paper will be limited to a description of certain metamorphosed sediments embraced within the oldest group of rocks that have been recognized, and which it is proposed to designate the Hutchison series.

HUTCHISON SERIES.

Only remnants of this terrain are now exposed to view, the series having been broken up by the great intrusions of igneous gneisses that succeeded. To this group of igneous rocks, the name—Flinders series—is given, from the hundred and county in which they attain a widespread and typical development. Fragments of the Hutchison beds have been engulfed in the Flinders gneisses, and these can be recognized at points remote from typical exposures of the Hutchison series. There is abundant evidence that this sedimentary terrain has been invaded and intensely metamorphosed by the succeeding igneous intrusions. The best exposures of the Hutchison series are developed along the coast of Sleaford Bay, and in the hundred of Hutchison in the hilly district west of Tumby Bay. At various intermediate points between the Sleaford Bay and Hutchison areas, these rocks emerge from beneath a mantle of weathered products, but no extensive unweathered outcrops have as yet been recognized. In a north-easterly direction in the county of Jervois, R. L. Jack has described dolomites associated with schists and gneisses, and doubtless these rocks represent the same series along the same line of strike. Undoubtedly the best exposures of these rocks are those outcropping on the shores of Sleaford Bay, near Sleaford mere. Here in a section of less than half a mile a most complex series of sediments is found, penetrated by granites and pegmatites of the Flinders series.

The beds, now exposed in a highly metamorphosed condition, comprise mica schists, garnet gneisses, graphite schists, graphite garnet gneisses, quartzites, dolomites, and calc-magnesian silicate rocks. The beds strike in a north–south direction, with a high angle of dip to the west (75 degrees) to vertical. Subsidiary folding and faulting have been observed. On the west they are bounded by granites and gneisses of the Flinders series, while on the east the beds disappear beneath calcareous sand rock and travertine, which here forms the coastline till the igneous rocks of Flinders intervene, near the Curta Isles, across the Bay.

In the Hutchison area the same types of metamorphosed sediments are to be found, but here the dolomites are more conspicuous, and calc-magnesian silicate rock do not form as important a feature as in the southern outcrops.

In the accompanying diagrammatic section (Fig. 1), the relations of the dolomite and diopside rocks are shown for the Sleaford Bay area. Only part of the Hutchison series exposed along the shore-line has been represented in this section, nor are all the diopside rocks revealed, there being a further development in a continuation of the section eastward.

SECTION ALONG THE SHORE AT SLEAFORD BAY.

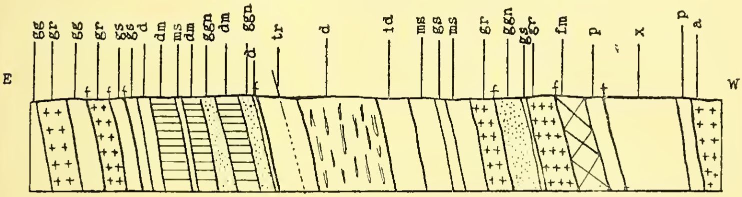

FIG. 1.

← — — — — — — — 500 yards — — — — — — — — →

a = Flinders gneiss.
p = pegmatite.
gr = granite.
f = ironstone band.
fm = forsterite marble.
gs = graphite schist.
ggn = garnet gneiss.
x = no exposure.
dm = diopside-microcline rocks.

d = diopside rock with quartz veins.
id = impure diopside rocks with micaceous bands.
tr = transition beds containing diopside, highly silicified, with fault breccia of silicified quartz rock.
gg = garnet-graphite gneiss.
ms = mica schists.

(Thickness of individual beds not to scale.)

Some of the exposures are badly weathered, and in some cases outcrops are missing, so that the succession cannot claim detailed accuracy.

Quartz veins from the neighbouring granites are often very abundant in the diopside rocks, and pegmatite veins are present, more especially in the graphite and garnet rocks. These rocks are, however, outside the scope of the present inquiry.

THE DOLOMITES OF THE HUTCHISON SERIES.

Dolomites form an important group of rocks of the Hutchison series. They range from practically pure dolomites to calc-magnesian silicate rocks, in which all traces of carbon dioxide have been removed. The evidences of all these rocks show that the pre-existing sediments were true dolomites or highly dolomitic limestones. Dealing now with those less impure types in which a carbonate mineral has been retained, we shall endeavour to describe their characteristics under the grouping of those developed at Sleaford Bay and those occurring in the Hutchison area.

(*a*) *The Sleaford Bay Section.*

The dolomites of the Sleaford Bay area are limited to a comparatively small exposure on the shore-line. Here they are associated with schists and gneisses intruded by pegmatites and granites in sill-like fashion.

As exposed on the beach, the marble outcrop is bounded on the east by a sill of hornblende granite and on the west by a coarse pegmatite. At its border it is replaced by ironstone. The exact thickness cannot be made out owing to the poorness of exposures, and large blocks evidently not in situ are present on the beach near at hand. When fresh it is a compact, cream-coloured rock, but on weathering its composite character is indicated by the selective weathering, the calcite, dolomite, and new-formed silicates being attacked differentially, leading to hollows and projections, the latter consisting mainly of dolomite with unaltered silicates. Thin sections of these rocks when examined under the microscope show an interesting suite of minerals, which include calcite, dolomite, forsterite, and an amphibole of the edenite-pargasite group. Rarely phlogopite and diopside may be seen.

Dealing with these minerals we have :—

(i) *Calcite.*—Abundantly present in rounded grains up to 1·5 mm. in size. Cleavages are usually present and twinning lamellæ (on the plane $01\bar{1}2$) are rarely to be observed. In sections which show the rhombohedral cleavages intersecting at the cleavage angle of 74 degrees the twinning lamellæ are seen to intersect the acute angle between the cleavages, and are parallel to the longer diagonal of the rhombohedron.

The distinction between calcite and dolomite was primarily effected by using Lemberg's solutions. Uncovered sections were treated with a dilute solution of ferric chloride for two minutes, washed and then immersed in ammonium sulphide solution, washed and finally treated with potassium ferricyanide, by which the precipitated ferrous sulphide is converted into Turnbull's blue. By this means calcite is stained blue, whilst dolomite remains unstained. This method has been found very satisfactory in differentiating these carbonates. The calcite grains in these rocks are remarkable for their turbidity and the dolomite for its limpidity. The clouded character is due to minute inclusions, some of which are transparent and of high refractive index. They are often quite ragged in outline, and appear not to be disposed along any particular direction. Others, usually more minute, are opaque, and their nature is not clear. In some calcite grains there are small granules of dolomite, clear and unstained, suggestive of a ramifying intergrowth. In one slice (115*a*) a primary twin of calcite-twin plane—($10\bar{1}1$)—is shown, the two parts having their vertical axes inclined at approximately 90 degrees, and the twin being bounded by prism and rhombohedron faces.

(ii) *Dolomite.*—As remarked above, this mineral has been distinguished by its unstained character when the section is treated with Lemberg's solution. Whenever it shows any definite outline, this outline is always idioblastic towards calcite, the reverse not being seen. The marked limpidity is a notable feature. Contrary to the usual statements in the literature, the dolomite in these slides is characteristically twinned, often showing rather wide hemitrope bands. In fact, it may be said that dolomite is more often twinned than calcite. The twinning law seems also to be of a different type to that of calcite. The plane $0\bar{1}12$ in dolomite is not a glide plane, and the twinning in these slides would correspond to twins on $0\bar{2}21$. Where a section shows the two cleavages intersecting at the rhombohedral angle, the twin bands intersect the obtuse angle between the cleavages and are parallel to the shorter diagonal of the rhomb. This point serves to distinguish it from calcite. In addition, then, to the staining differentiation for these rocks, we can apply the following criteria :—

(1) Twinning in dolomite is at least as common as in calcite, and is often more so. Moreover, the twinning is of a different type. In dolomite the twin plane is $0\bar{2}21$, and in calcite $0\bar{1}12$. In favourable sections, such as those showing the cleavages intersecting at the rhombohedral angle, the lamellæ cut the intercleavage angle, such that in dolomite they are usually parallel to the shorter diagonal of the rhomb, and in calcite are parallel to the longer diagonal. The twinning in dolomite would appear to indicate that the plane $0\bar{2}21$ is also a glide plane.

(2) Where the one mineral exerts its form against the other dolomite is always the idioblastic mineral.

(3) Dolomite is usually of a remarkably limpid character, whilst calcite is invariably turbid, owing to the presence of minute inclusions. The significance of this will be dealt with later. This feature can be safely used to differentiate calcite and dolomite in the rocks under discussion, and is the most important of the three criteria.

(iii) *Forsterite.*—Builds rounded grains or crystals with elongation parallel to the *c* axis in size up to 1·5 mm., rarely larger. In some grains the 010 cleavage, the trace being parallel to the elongation, is very distinct, but it may be completely absent. Apart from its characteristic decomposition products, it is distinguished by its large optic axial angle, positive sign, and the position of the optic axial plane with reference to the 010 cleavage. The characteristic cracks and the serpentinous decomposition parallel the occurrence of its ferriferous member in the eruptive rocks. In some sections (115) the forsterite is now represented by aggregates of opal and calcite. The determination of calcite within the forsterite outline was settled by a staining test.

(iv) *Edenite.*—This is a clear, colourless mineral, idioblastic, with a moderate refractive index, which occurs sparingly in these rocks, embedded in calcite or dolomite.

Several sections show the typical amphibole cross-section cleavages intersecting at an angle of 124 degrees. The crystals are optically positive, and extinctions of 25 degrees have been observed. These properties do not correspond with those of ordinary tremolite. Moreover, a basal section yields only a very low interference colour, and in convergent light such sections are seen to be almost normal to an optic axis. The optic axial angle is not large, and the plane of the optic axes bisects the obtuse intercleavage angle as in normal amphiboles. These characters serve to identify the mineral as a member of the edenite-pargasite series. If we restrict the name edenite to the colourless members of this group, then this mineral must be classed as edenite.

Kreutz[1] has described a pargasite, from Pargas, Finland, containing 10·83 per cent Al_2O_3, 1·56 per cent FeO, 0·76 per cent Fe_2O_3.

The optical properties are given as R.I. = 1·62, D.R. = ·0195, optically positive, 2V = 59 degrees, $Z \wedge c$ = 27 degrees.

W. E. Ford,[2] in an optical study of the amphiboles, describes an edenite from Grenville township, Canada, containing 11·37 per cent Al_2O_3, FeO=0·42, Fe_2O_3=0·42. The double refraction approximated ·020, optically positive, 2V = 56 degrees, and the extinction $Z \wedge c$ = 29 degrees.

Coomaraswamy,[3] in describing the crystalline limestones of Ceylon, gives the analysis of an aluminous tremolite, Al_2O_3 = 13·76. The optical properties are not given, but material from another locality gave extinctions on 110 cleavage flakes of 17 degrees, which would approximate the edenite values on 010.

In view of these descriptions, and the parallelism of the optical properties of the material in those dolomites, with those described for the edenites by Kreutz and Ford, we can have little doubt in assigning this mineral to the edenite group.

Unfortunately the material at disposal and the comparative scarcity of the mineral in the rock, has not enabled a chemical analysis to be made. Some sections, cut parallel to the vertical axis showing a single cleavage, are with difficulty distinguishable from colourless diopside, the optical orientation of which is closely similar.

(v) *Alteration Products of Forsterite.*—Forsterite is, as has been noted, usually in part, or wholly replaced by other minerals, amongst which serpentine, calcite, rarely dolomite or magnesite, and opal are the chief.

Serpentine may be developed to the exclusion of the carbonates or opal. Calcite has been definitely proved in certain cases, and a few

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[1] S. Kreutz, Min. Mitt., vol. xxvii, 1908, p. 249.

[2] W. E. Ford, Amer. Journ. Sci., vol, xxxvii, 1914, p. 179.

[3] A. K. Coomaraswamy, Quart. Journ. Geol. Soc., vol. lviii, 1902, p. 417.

unstained grains in certain of the pseudomorphs indicate dolomite or even magnesite, the distinction between these two minerals not being possible.

(115) is a good example of the replacement by opal and calcite. The opal generally forms a border to the pseudomorph, and by its extension across the grain often separates the calcite into isolated grains. The relative positions of forsterite with regard to calcite and dolomite call for remark.

An examination of the slides shows that in the great majority of cases the forsterite is embedded in calcite. In almost all cases there is present some calcite abutting forsterite crystals.

(*b*) *Dolomites of the Hutchison Area.*

The dolomites of the Hutchison area are well developed in the hilly district behind Tumby Bay, and good exposures are met with in the gorge of the Mine creek.

Serpentinous marbles outcrop in the north-eastern corner of section 63 in the hundred of Hutchison, and are here striking east with an almost vertical dip. Marbles are again met with near the Copperinga mine in section 804. Here serpentine occurs in bands and lenses through the rock. In a tributary stream—the Waterfall Creek—the marble makes a prominent cliff-face with a large angle of dip, and striking approximately north-east. A drive into the side of the hill shows veins of chrysotile asbestos up to half an inch in width. The associated rocks are garnet gneisses. On the west the marbles are bounded by mica schists and pegmatized schistose rocks. Graphite has been observed in these schists. The whole series has been invaded by the granite gneisses, which have their best development in the Mine Creek to the east. These rocks present the same characteristics as those at Sleaford Bay, and represent the same series of sediments now highly metamorphosed.

To the north-east, in the adjoining county of Jervois, R. L. Jack[1] has noted crystalline dolomites, associated with quartzites, schists, and gneisses in the hundreds of Dixon and Miltalie. These rocks outcrop along the strike extension of the "graphite line" in the county of Flinders. No detailed petrological examination of these dolomites is reported, but Jack indicates the presence of forsterite, tremolite, and diopside.

Analyses of three dolomites from different localities in this area show a range of the CaO/MgO ratio from 1·0 to 1·9. The series has been invaded by granitic and pegmatitic intrusions.

In addition to the minerals found in the Sleaford Bay exposures, there are rocks in this district containing spinel, phlogopite, apatite, diopside, chrysotile-asbestos, talc, and magnetite. Some of the dolomites are now represented by ophicalcites, in which dolomite is only sparingly present, and may be absent. There has in these

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[1] R. L. Jack, Bull. No. 3 Geol. Surv. S. Austr., 1914, pp. 11–12.

cases been sufficient detrital silica to combine with all magnesia to form forsterite.

Dealing with these minerals we have :—

(i) *Spinel.*—This mineral is characteristically of a light-green tint, building little rounded grains or more rarely idioblastic. The green coloration is to be ascribed to ferrous iron, indicating a member of the pleonaste group. It may be present isolated in calcite or dolomite, and also abutting or enclosed in original forsterite grains, which now consist of forsterite residues surrounded by serpentine. In some examples the spinel is bordered by a thin ring of serpentine, presumably derived from it. Marbles containing abundant light-green spinel are well developed in the north-eastern corner of section 63, hundred of Hutchison.

(ii) *Phlogopite.*—This is an important constituent of the marbles of this area. It is colourless to a very light brown, and is often much bent and contorted. Cleavage-flakes give an interference figure normal to an acute bisectrix, but the optic axial angle is so small that the opening of the hyperbolæ is very slight. It shows peripheral and intercleavage alteration to a chloritic product.

(iii) *Apatite.*—Is developed in little rounded to sub-hexagonal grains, showing uniaxial negative character. It is commonly associated with rocks in which phlogopite is present.

(iv) *Chrysotile-Asbestos.*—Occurs in irregular veinlets in yellow-green serpentine in the gorge of the Mine Creek. The fibres are always elongated at right angles to the length of the veins.

Under the microscope the asbestos is seen to be present in anastomosing veins, cutting across the mass of serpentine. The refractive index is less than that of C. balsam. It is optically positive, and the optic axial plane is parallel to the length of the fibres. The elongation is positive and the extinction is straight.

(v) *Diopside.*—Occurring in the same marble are nodular masses of green diopside, associated with vein quartz, to which the formation of diopside is due. Where the quartz vein has penetrated the dolomite it is surrounded by a ring of the green silicate. The pyroxene has not been definitely found in this locality other than with this association, but in other places it occurs as a normal product of metamorphism not involving addition of material.

(vi) *Forsterite.*—The serpentinization of the olivine of these rocks is accompanied by a separation of magnetite granules at the borders of the pseudomorphs and betrays the original presence of a ferriferous forsterite. There must still be considerable iron present in some of the serpentine, judging by the strength of colour that is developed (328). In other cases the forsterite is clear and unaltered (290).

Hæmatite may take the place of magnetite bordering serpentine pseudomorphs (313).

In the absence of silica the rock has recrystallized without change. No. 307, from an outcrop in section 804 treated with Lemberg's solution, remained unstained with the exception of a very small amount of calcite. The specific gravity is in conformity with this determination, being 2·84. There are a few flakes of phlogopite and a few grains of an amphibole, possibly edenite.

Nodular masses of yellow-green serpentine are present in a zone of the same outcrop up to 2 inches in diameter, and occasionally larger masses are met with. It is with these that the chrysotile veins are associated. The specific gravity of homogeneous fragments of the serpentine varied from 2·55 to 2·56. The specific gravity of the ophicalcite rocks is close to 2·70, and vary from 2·69 to 2·72. This can be ascribed to a changing distribution of serpentine and concurrently the coming in of dolomite.

CHEMICAL CHANGES INVOLVED IN METAMORPHISM.

The mineralogical features of this suite of rocks are those characteristic of metamorphism of the thermal type, and there is no evidence that shearing stress has played any important rôle. In the rocks under discussion we can also exclude magmatic additions as being inoperative, with the possible exception of such a volatile constituent as water. It is clear that apart from detrital impurities, like silica and alumina, the sediments were true dolomites or dolomitic limestones, with a high percentage of magnesia. As to the origin of the dolomitization it is clearly anterior to this epoch of metamorphism, and there seems little reason to doubt that it is the result of metasomatic processes subsequent to the deposition of the rocks. At the time of metamorphism we can safely assume that they were dolomitic sediments with a certain amount of silica and alumina of detrital origin. In the first place, the chemical changes involved have been the elimination of carbon dioxide in so far as this has been possible by reactions, involving the material of detrital origin. In the absence of such reactions there has been a recrystallization of the carbonate minerals. In no case has the simple decarbonation of the magnesite molecule of dolomite taken place to periclase. It is to be inferred that at the temperature prevailing the pressure was in excess of that necessary to effect any appreciable disruption of the dolomite molecule, in the absence of silica or alumina.

At a given pressure the temperature of decomposition must be considerably lower for dolomite in the presence of silica or alumina. In these rocks reactions involving these constituents have proceeded to completion. The reactions involved bring out very clearly the greater chemical reactivity of magnesia as compared with lime, a point which is, of course, the basis of Teall's dedolomitization principle. Dominant lime-bearing minerals, as the garnets, vesuvianite, wollastonite, etc., are conspicuous by their absence, and when they do appear it is usually after all magnesia has been satisfied. For example, scapolite and bytownite appear in associated rocks originally so impure that their metamorphism is accompanied by complete elimination of carbon dioxide. These lime-bearing minerals are sufficiently familiar in the metamorphism of the calcareous limestones.

The production of forsterite from dolomite involves the simultaneous formation of calcite, as indeed does the formation of all the minerals involved in these rocks, with the exception of a non-aluminous diopside. The equations representing the production of forsterite, edenite, and diopside are shown below.

$$(1)\quad \underset{\text{dolomite}}{2\ CaMg\,(CO_3)_2} + \underset{\text{quartz}}{SiO_2} = \underset{\text{forsterite}}{Mg_2SiO_4} + \underset{\text{calcite}}{2\ CaCO_3} + 2\ CO_2$$

$$(2)\quad 3n + 2\ \underset{\text{dolomite}}{(CaMg\,(CO_3)_2)} + 4n + 3\ (SiO_2) + Al_2O_3$$

$$= \underset{\text{edenite}}{\underset{CaMg_2Al_2\,(SiO_4)_3}{n\ CaMg_3\,(SiO_3)_4}} + 2n + 1\ \underset{\text{calcite}}{(CaCO_3)} + 4n + 3\ (CO_2)$$

$$(3)\quad \underset{\text{dolomite}}{CaMg\,(CO_3)_2} + 2\ SiO_2 = \underset{\text{diopside}}{CaMg\,(SiO_3)_2} + 2\ CO_2$$

The ratio $R = \frac{SiO_2 + Al_2O_3}{CaO + MgO}$ becomes an important criterion in the formation of these minerals.[1] Considering the case where alumina is zero, the production of forsterite, tremolite, and diopside is conditioned by the value of R, being $\frac{1}{4}$, $\frac{2}{3}$, and 1 for these minerals respectively. For the aluminous amphibole-edenite R becomes $\frac{2n + 2,}{3n + 2}$ where n is the ratio of tremolite molecules to Scharizer molecules. In the presence of increasing silica, forsterite gives place to first tremolite, and then diopside, and this order is one of decreasing dedolomitization. The formation of any one of these minerals can be regarded as dependent on the amount of silica present (i.e. R) in thermal metamorphism, or the amount of dolomite involved within the sphere of diffusion of silica.

The presence of alumina in the absence of silica, possibly as bauxite leads to the formation of spinel as represented in the equation

$$CaMg\,(CO_3)_2 + Al_2O_3 = \underset{\text{spinel}}{MgAl_2O_4} + CaCO_3 + CO_2.$$

When silica is present the spinel may accompany forsterite, and the close association of spinel and forsterite as seen in the thin slices,—spinel often present within the boundaries of forsterite, or abutting forsterite grains, is evidence of co-crystallization in accordance with the equation

$$3\ CaMg\,(CO_3)_2 + SiO_2 + Al_2\,O_3 = Mg_2SiO_4 + MgAl_2O_4 + 3\ CaCO_3 + 3\ CO_2.$$

The value of R is here $\frac{1}{3}$.

Apparently when R exceeds this value, spinel is less often formed,

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[1] Or in general for magnesian limestones, $R = \left(\frac{SiO_2 + Al_2O_3}{MgO}\right)$, with the modified R values for these minerals.

and alumina enters the amphibole or pyroxene molecule which arises in this case.

So much can be gathered from an inspection of the rocks under discussion. The associations tremolite–spinel, diopside–spinel are not to be seen in the slides.

That alumina is absorbed into the silicate molecule is abundantly confirmed by the presence of the aluminous tremolite, edenite. The presence of possible alumina in the diopside is not so easily made evident by optical determinations.[1]

It seems reasonable to conclude that forsterite and spinel occur together with a value of R equal to one-third, and that when this value is exceeded spinel does not form, and the alumina is absorbed in the metasilicate molecule in accordance with the excess silica either in amphibole or in pyroxene. If spinel is found associated with the metasilicate, it indicates that the original distribution of the detrital materials in the rock was such that they were not involved within a common sphere of diffusion, that is, part was without the radius of diffusion of the remainder, and thus a limiting value of the amplitude of diffusion in thermal metamorphism might be thereby established.

Coming now to the more complex mineral phlogopite, its formation is to be ascribed to the same period of metamorphism, but the detrital materials were in this case of somewhat different nature. The potash and alumina are doubtless derived from detrital sericite present in the original sediment.

Accepting F. W. Clarke's views of the constitution of the micas,[2] we may write phlogopite as $H_2KMg_3Al\,(SiO_4)_3$, and the following equation may represent its formation, when it is accompanied by spinel, as is often the case in the rocks under discussion :—

$$\underset{\text{dolomite}}{4\,CaMg\,(CO_3)_2} + \underset{\text{sericite}}{H_2KAl_3\,(SiO_4)_3} = \underset{\text{phlogopite}}{H_2KMg_3Al\,(SiO_4)_3} + \underset{\text{spinel}}{MgAl_2O_4}$$
$$+ \underset{\text{calcite}}{4\,CaCO_3} + 4\,CO_2$$

In some rocks, however, this mineral is not accompanied by spinel, and the above equation cannot represent the formation of phlogopite in these cases. To produce phlogopite of this composition alone, requires dolomite to interact with the oxides $K_2O : Al_2O_3 : SiO_2$, in the ratio 1.1.6, or the proportions present in felspar. This mineral, however, is unlikely to be present in any original dolomitic sediment, representing the mature weathering product of pre-existing rock-masses. The ultimate derivation of phlogopite in these rocks must be ascribed to detrital sericite, and there is no reason to infer that there has been an addition of magmatic material other than the purely volatile agents, water and hydrofluoric acid. By adjusting the relative amounts of the isomorphous elements,

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[1] According to V. Schumoff-Deleano (Centr. Min., 1917, p. 290) diopside can take up 15 per cent Al_2O_3 in solid solution.

[2] F. W. Clarke, Bull. U.S.G.S., No. 616, 1916, p. 393.

H and K, in the phlogopite constitution, we may represent its formation by the succeeding equation

$$9\,\underset{\text{dolomite}}{\mathrm{CaMg\,(CO_3)_2}} + \underset{\text{sericite}}{\mathrm{H_2KAl_3\,(SiO_4)_3}} + \underset{\text{quartz}}{6\,\mathrm{SiO_2}} + 3\,\mathrm{H_2O}$$

$$= \underset{\text{phlogopite}}{2\,\begin{matrix}\mathrm{H_3Mg_3Al\,(SiO_4)_3}\\ \mathrm{H_2KMg_3Al\,(SiO_4)_3}\end{matrix}} + \underset{\text{calcite}}{9\,\mathrm{CaCO_3}} + 9\,\mathrm{CO_2}$$

Hydrofluoric acid being regarded as an essential constituent of phlogopite, this will replace some of the water in the left-hand side of the equation, entering the phlogopite molecule as the univalent radicle, MgF, isomorphous with H and K.

Whatever equation is adduced for the formation of phlogopite, calcite is inevitably a by-product of the reaction, and phlogopite must therefore be added to the group of minerals which induce by their formation dedolomitization.

Apatite is doubtless derived by the recrystallization of original phosphate substance in the sediment, possibly of organic origin or of detrital apatite of pre-existing rocks.

The apatite is observed to be plentiful in those rocks in which phlogopite is most abundant, and this association may have been accentuated through the agency of fluorine.

The presence of calcite as a constituent of decomposed forsterite grains calls for some remark.

The changes which have operated since the formation of forsterite are firstly its replacement by serpentine, with or without the separation of magnetite, and this may be represented by the equation

$$2\,\mathrm{Mg_2SiO_4} + 2\,\mathrm{H_2O} + \mathrm{CO_2} = \mathrm{H_4Mg_3Si_2O_9} + \mathrm{MgCO_3}$$

The magnesium carbonate is either removed in solution or is absorbed into the calcite or dolomite molecule during this change. The change has in many cases proceeded further, however, and in the dolomites of Sleaford Bay serpentine has yielded pseudomorphs of opal and calcite.

$$\mathrm{H_4Mg_3Si_2O_9} + 3\,\mathrm{CO_2} = \underset{\text{opal}}{2\,\mathrm{SiO_2}} + 3\,\mathrm{MgCO_3} + 2\,\mathrm{H_2O}$$

Here, again, magnesite is released, and although this may be present in some of the pseudomorphs, yet in the majority its place is taken by calcite.

The origin of the magnesite so characteristically associated with the graphite schists in the vicinity, and developed in large masses in the northern area, and essentially of secondary origin, can probably be traced in part to those reactions which have ultimately resulted in the degradation of forsterite to opal and calcite.

The conversion of the compact serpentine into the fibrous chrysotile asbestos is apparently a recrystallization in situ, under conditions of non-uniform pressure, in which case the veins represent potential fractures, the elongation of the resulting chrysotile fibres being normal to the direction of maximum pressure.

It can be considered that the veins have arisen as a consequence of the stress set up during the hydration by probably meteoric waters of the original forsterite to compact serpentine. Potential fractures arising through this agency, the minute fibres of heterogeneous orientation, are subject to an active unequal pressure in the vicinity of the points of potential fractures, such that in recrystallizing solution takes place in those fibres oriented across the direction of minimum pressure, only to be redeposited on those fibres whose elongation is parallel to the direction of minimum pressure, uniform cross fibre veins thus arising.

The relationship of the new-formed calcite to forsterite.

Teall,[1] first pointed out that forsterite formed during metamorphism was intimately associated with the new-formed calcite and usually in direct contact. It has already been remarked that the same features are to be seen in the rocks under discussion, and in many cases the association is very striking. The forsterite may be wholly embedded in calcite or partly surrounded by an aureole of this mineral. Crook[2] has pointed out that in many examples of forsterite marble studied by him the silicate is separated from the calcite by a thin ring of dolomite. No cases of this nature have been found in these marbles. The distribution of dolomite, calcite, and forsterite is often best seen by staining a thick slice of the rock and then covering with a cover-glass. The individual grains can then be easily made out with a lens.

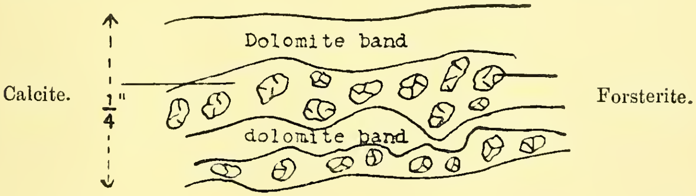

Fig. 2.—Diagrammatic sketch of portion of a flat surface of dolomite.

A dolomite from the Hutchison area treated in this way was seen to consist of bands of unstained dolomite, alternating with a band in which the forsterite grains are concentrated, and of calcite (see Fig.2).

This appears to afford evidence that we have here to deal with bands of originally differing composition, viz. dolomite bands free from impurities and containing detrital silica respectively. As a result of the formation of forsterite, the siliceous band is dedolomitized, the newly formed forsterite being surrounded by recrystallized calcite derived from the reaction. These examples serve to confirm the view that the radius of diffusion in thermal metamorphism is confined within comparatively narrow limits.

[1] J. J. H. Teall, Geol. Mag., 1903, pp. 513–14.

[2] T. Crook, Geol. Mag., 1911, pp. 339–45.

The occurrence of small grains of spinel embedded in dolomite without proximity to calcite may perhaps be explained by assuming that the new-formed calcite is completely absorbed within the dolomite molecule—the evidence pointing to the view that there is a limited miscibility of these two minerals, conforming, presumably, to Type 5 of Roozeboom's classification.[1]

The criteria for the distinction of dolomite and calcite.

The three criteria which are available for the distinction of dolomite and calcite in some of these rocks have already been mentioned. Of these the most important is the distinction based on the turbidity of the new formed calcite. The dolomite, on the other hand, is remarkable for its clarity and limpid character. The turbidity of the calcite, when examined under the high power, is seen to be related to the presence of minute inclusions of two types, one colourless to greyish particles of high refractive index, and certain opaque particles of uncertain nature, but perhaps carbonaceous. However this may be, it is evident that the turbidity is of general occurrence. Some of the particles may be of detrital origin, and their presence in calcite and absence in dolomite may stand related to the position of these minerals in the crystalloblastic series.

Dolomite is the stronger mineral, and is usually idioblastic towards calcite. During recrystallization foreign material may be discharged, only to be absorbed within the weaker and more yielding calcite.

All these criteria are to be found in the literature on the constitution of the crystalline limestones, but the data are somewhat confusing. The criteria as noticed here are somewhat similar to those advanced by Lacroix[2] for the limestones of Ceylon, and later by Fermor[3] for the crystalline limestones of the Chhindwara district, India.

Some of them are diametrically opposed to the criteria summarized by Renard,[4] and reprinted in the textbooks. Fermor would explain his own examples (apparently as abnormal), and presumably those of Lacroix, by the suggestion that the carbonates have been formed direct from silicates, and not by the alteration of pre-existing calcite. Whilst it is true that the carbonates in the rocks under discussion have been recrystallized, there is not the slightest evidence that this silicate derivation obtains. They are recrystallization products under the influence of thermal metamorphism, the majority of the calcite being released from original dolomite molecules.

(*To be continued.*)

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[1] R. C. Wallace, Compte-Rendu XII^e session Congrès Géologique International, Canada, 1913, pp. 882–3.

[2] M. Lacroix, Rec. Geol. Surv. India, vol. xxiv, 1891, pt. iii, pp. 191–2.

[3] L. L. Fermor, ibid., vol. xxxiii, 1906, pt. iii, pp. 195–7.

[4] A. F. Renard, Bull. Acad. Royale de Belgique, vol. xlvii, 1879, No. 5, p. 557.

On the Investigation of the Mechanical Constitution of Loose Arenaceous Sediments by the method of Elutriation, with special reference to the Thanet Beds of the Southern Side of the London Basin.

By Herbert Arthur Baker, M.Sc., F.G.S.

(*Concluded from p. 420.*)

VELOCITIES OF THE CURRENTS FROM WHICH THE THANET BEDS WERE DEPOSITED.

THE speeds of the currents employed in the elutriation process in sorting diversely sized material bear no relation whatever to the speeds of the currents, which are competent to transport the same material. The elutriation process in no way imitates the natural processes whereby sediments are transported, sorted, and deposited. The determination of competent velocities in relation to size of material transported is quite a distinct investigation, and one which still calls for much study in spite of the time and attention given to it by numerous workers.

A conclusion which appears to be very generally held is that the diameter of the largest particle a current can move is proportional to the square of the velocity. This is the conclusion to which the theory of impact and transport by a current leads, and results obtained by a large number of investigators appear to endorse it. The law may be stated in the form :—

$$d = kV_c^2$$

where d = diameter of largest particle transported,
k = a constant,
and V_c = the speed of the current which is just competent to transport the particle.

Difficulty arises, however, as soon as we endeavour to assign a definite value to the constant k. On this point the writer examined the experimental results of many investigators, and found no approach to agreement as to the value of this alleged constant factor. It appears that the value to be assigned to k varies with the class of phenomena observed, and is affected by such considerations as whether the particle under transport is to be regarded as (*a*) an isolated body being transported over a bed of similar material, (*b*) an isolated body being transported over a bed of different material, either finer or coarser, or (*c*) an individual particle in a mass of similar material, the whole of which is in process of transport.

In endeavouring to obtain some idea of the speeds of the currents from which the Thanet Beds were deposited, search was first made for data which would afford a value for the factor k in the case of phenomena of type (*c*) above; but, although a considerable amount of experimental work on the speeds of currents competent to transport sands and gravels of varying degrees of coarseness has been done, the writer could discover no trustworthy case in which the work had been accompanied by accurate determination of the mean diameter of the material used in the experiments. Dr. John S. Owens,[1] however, made observations in the case of phenomena of type (*b*) above, and it was found possible to make use of his results. He carried out experiments on the transporting power of sea-currents, using flint pebbles ranging in diameter from half-an-inch to six inches. The pebbles were rolled by the currents over a sand surface. As a result of his experiments, Owens arrived at the formula :—

$$d = \frac{45V^2}{W - 64}$$

where d = diameter of pebble in inches

W = weight of a cubic foot of pebble material in pounds,

V = velocity, in feet/sec. of current just competent to transport the pebble.

Now it seems legitimate to argue that, where we have flint pebbles scattered throughout a bed of sand we may fairly assume that the same conditions were required for the deposition of the pebbles as for the sand. The observations of Owens, Vaughan Cornish, Gilbert, and others, have, however, shown that when arenaceous material is under transport by currents of lower velocity than 2·5 feet per second it invariably moves forward in the form of sand-ripples, and the rippled surface always arrests the movement of pebbles unless the velocity of the current is greatly in excess of that required to move them. According to the formula given by Owens, at a speed of 2·5 feet per second, a current would be able to transport flint pebbles up to 2·85 inches in diameter. Therefore, where we have a bed of sand with flint pebbles scattered fairly uniformly through it, and these pebbles clearly average less than 2·85 inches in diameter, we may assume that the current which transported the material to its present resting-place, and from which it was deposited, was *at least* as fast as that required to transport pebbles of the size seen, since the arrest and burial of these pebbles was probably brought about in consequence of the formation of sand-ripples on the bed. We may assume further, that the velocity of the current was not *greatly* in excess of that required to move pebbles of the size seen, for, had it been so, the sand-ripples would not have checked the pebbles in their career.

The Thanet Beds contain no flint pebbles, but after some search the writer selected a section in Blackheath Pebble Beds in which numerous flint pebbles, averaging less than 2·85 inches in diameter, but of notable uniformity of size, were evenly distributed throughout a bed of sand. A sample was taken containing both pebbles and sand. One hundred representative pebbles were selected and their

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[1] Owens, "Experiments on the Transporting Power of Sea Currents": Geog. Journ., April, 1908, pp. 415–20.

total volume found by displacement. The diameter of the average pebble, assumed spherical, was then calculated. The result was 2·197 cm. The average specific gravity of the flint was then determined (2·59) and the weight in lb. of a cubic foot of flint calculated (161·69). These figures were then applied to Owens' formula thus:—

$$d = \frac{45V^2}{W - 64}$$

$$\cdot 02197 \times 39\cdot 3708 = \frac{45V^2}{97\cdot 69}$$

giving $V = 1\cdot 37$ ft./sec.

This value may be taken as the *minimum* speed (probably not much below the true speed) of the current from which the sand associated with the pebbles was deposited. A minute mechanical analysis of the sand was next made, the elutriation-curve drawn, and the Equivalent Grade figure determined with great precision (·102 mm.). The sand proved, fortunately, to give a curve of remarkable similarity to a Thanet Sand of intermediate type, with a fairly high Grading Factor. The Equivalent Grade of the sand was taken as the representative diameter of the material. It was a figure on which much reliance could be placed, in view of the high Grading Factor. Then, by substitution in the formula

$$d = kV_c^2$$

the value to be assigned to the factor k (for transport of sand in bulk) was ascertained, thus:—

$$\cdot 102 = k \times (1\cdot 37)^2$$

d being taken in mm. and V in feet per second.

Hence $k = \cdot 054$.

The value of k, as obtained directly from Owens' formula (by substituting in it the weight in lb. of a cubic foot of quartz), is of a much larger order than that obtained above, so that velocities calculated by means of it are much less than those obtained when taking the value indicated above. It has long been known, however, that an aggregate requires higher velocity to move it than does a single object. T. E. Blackwell demonstrated this in 1857, and Owens himself noted that the velocities required to move sand-grains in the mass were several times greater than the velocities as calculated from his formula, on substituting in it the diameter of the individual grains. In view of the use to which the above result was to be put, the writer thought it well to check the formula by repeating the experiment with a fresh sample of sand containing flint pebbles obtained from another area. A second sample was taken, this time from the lower part of the Woolwich and Reading Beds, at a spot many miles distant from the place whence the first sample had been obtained. The result was remarkable. The hundred representative pebbles gave an average diameter very near that obtained in the first experiment

(2·211 cm. as compared with 2·197 cm.), and the Equivalent Grade of the associated sand similarly gave a figure extraordinarily near that obtained in the case of the first sand (·106 mm. as compared with ·102 mm.). If this be not a singular coincidence it must indicate a significant connexion between the size of the pebbles in a sandy bed and the Equivalent Grade of the sand itself. With regard to the considerable variation often to be seen in the sizes of pebbles included in a sandy bed, it should be borne in mind that the *weight* of stone which a current can move varies as the *sixth* power of the velocity, and that therefore a slight increase in velocity may produce effects out of all proportion to what would be expected. The determination of k from the data of the second experiment gave ·056 as compared with ·054, the value obtained previously, and accordingly ·055, the mean of these two results, was taken. Hence, for the case of the transport, in bulk, of arenaceous material similar to that of which the Lower London Tertiary strata of the southern side of the London Basin are composed, the formula

$$d = {\cdot}055\, V_c^2$$

where d is the Equivalent Grade of the material in mm. and V_c is the velocity in feet/sec. just competent to transport the material, is put forward with a certain amount of confidence.

LOWER THANET BEDS.

	Beddington.	Charlton.	Swanley.	East Kent.
Equivalent Grade of material in mm.	·085	·059	·073	·037
Competent Velocity ft./sec.	1·24	1·03	1·15	0·82

UPPER THANET BEDS.

	Charlton.	East Wickham.	Greenhithe.	Pegwell Bay.[1]
Equivalent Grade of material in mm.	·146	·120	·090	·042 for highest Thanet Beds seen.
Competent Velocity ft./sec.	1·63	1·48	1·28	0·87

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[1] The highest Thanet Beds seen at Pegwell Bay really represent a fairly low level in the deposit, but these data are included here because they were used in the diagram (Fig. 8).

By means of the formula the speeds of the currents just competent to transport various types of Thanet Beds material were calculated. The velocities obtained may be regarded as minimum values for the rates of movement of the water from which the Thanet Beds were deposited.

The localities mentioned in the second table being approximately in alignment, from west to east, it is of interest to plot a graph showing the relation between competent velocities and distances. When this is done the points are found to lie on a curve of logarithmic type, and when competent velocities are plotted against the logarithms of the distances the points lie very nearly in a straight line (see Fig. 8). In the case of the Pegwell Bay data, however, the point lies somewhat below the line, but this is what was expected. The highest Thanet Beds seen at Pegwell Bay really belong to the lower part of the deposit, and higher values for the Equivalent Grade and competent velocity would have been yielded by a sample from a higher level, had one been available. These results suggest that we have here a hopeful line of research, the following up of which may be expected to yield comparative results of a reliable nature.

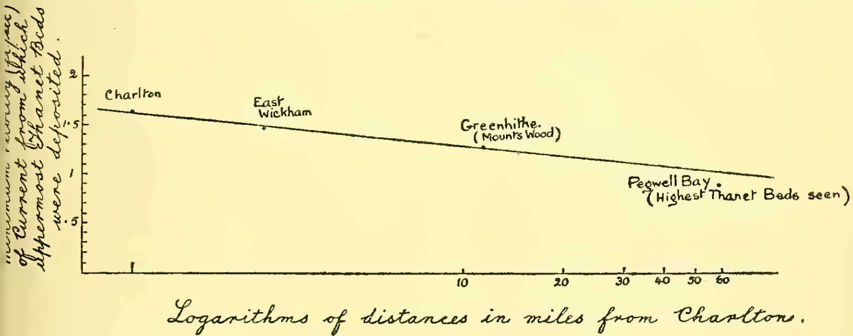

FIG. 8.

In view of the influence of shore-lines upon marine currents, the writer is of opinion that the construction of a map indicating the competent current values for the Thanet Beds of the London Basin could not fail to throw much useful light upon the question of the origin and development of the great trough.

The results of similar work upon the mechanical constitution of the Woolwich and Reading and Oldhaven Beds are reserved for future discussion.

REVIEWS.

Special Reports on the Mineral Resources of Great Britain. Vol. XI: The Iron Ores of Scotland. By M. Macgregor, G. W. Lee, G. V. Wilson, T. Robertson, and J. S. Flett. Mem. Geol. Survey. pp. vii + 240, with 18 text-figures. Edinburgh, 1920. Price 10*s.* net.

THE fourth volume of this valuable series to be devoted to iron-ores gives a very complete and comprehensive account of those of Scotland, both of actual and potential value. The first section, of a historical nature, gives an interesting sketch of the early and very remarkable attempts at the smelting of iron-ores from England and elsewhere by means of charcoal derived from the forests of the Highlands, which seem to have had a real existence in those days, outside of the imaginations of English Socialist propagandists. Thus in the eighteenth century furnaces were erected for the smelting of iron in such extraordinary places as Bonawe, Glenkinglas, Invergarry, Strathspey, and Loch Maree, the ore being brought from the coalfields of Central Scotland and from Cumberland. Naturally this industry did not enjoy a long life, but strangely enough the Lorne Furnace at Bonawe seems to have struggled on spasmodically till 1876.

Effective iron-mining in Scotland may be said to have begun in 1760, when the Carron Ironworks started to smelt clayband ores with coal. Soon after this great development began in the Carboniferous bedded ores, giving rise to an industry of first-rate importance. The greater part of this memoir is naturally taken up by a detailed description of the occurrences of this type, which are found over a large area in the central parts of Scotland, ranging with intervals from Ayrshire to Fife, the greatest developments being in Lanarkshire and the adjoining counties, here called the Central Coalfield. This section cannot fail to be of the greatest value to Scottish mine-owners and geologists. Careful and apparently conservative estimates are made of probable and possible reserves.

The non-Scottish geologist will, however, undoubtedly turn with greater interest to the accounts here given of some of the side-shows, such as the Jurassic ores of Raasay and the remarkable veins of the Orkneys and Shetlands. The Raasay bed, which is now known to belong to the Upper Lias, though at first considered to be the equivalent of the Cleveland Main Seam, has actually been a producer, but it is doubtful whether it could be made to pay under peace conditions, owing to high cost of transport. An analysis of an average specimen of the raw stone, quoted in this memoir, gives 25·2 per cent of metallic iron with 2·3 per cent of phosphoric acid, while Dr. Hatch states that it averages about 23 per cent, with 0·9 per cent phosphorus. The stone is therefore of low grade.

We are glad to note that in this memoir a glossary is given of the extraordinary language in which the Scottish mining geologists have effectively concealed their thoughts from the Southerner in other publications dealing with the coalfields of the same areas.

R. H. R.

Invertebrate Palæontology: An Introduction to the Study of Fossils. By H. L. Hawkins, M.Sc., F.G.S. pp. xix, 226, with 16 plates. London: Methuen & Co. 1920. Price 6*s.* 6*d.* net.

THIS book is apparently intended for those who are beginning the study of fossils, and also for students who have already some knowledge of palæontology. The first four chapters deal with the scope and aim of palæontology; the nature, occurrence, preservation, collecting, and preparation of fossils; and with stratigraphical and physiographical palæontology. These chapters are written in a clear and interesting style, and with the accompanying illustrations should prove attractive to beginners.

The second part of the book "is designed to give an epitome of the sequence of evolution as it has been unfolded in geological time". This part is divided into (1) Pre-Cambrian Faunas, (2) Lower Palæozoic Faunas, (3) Upper Palæozoic Faunas, (4) Mesozoic Faunas, (5) Cainozoic Faunas. By taking these relatively long time-divisions the author is able to give a more continuous account of the general evolutionary changes in the various groups of fossils than is possible when the life of each geological system is considered separately. But, as the author points out, this part of the book will be intelligible only to those readers who have some considerable knowledge of morphological and systematic palæontology; and the same remark applies to the preceding chapter on "Biological Palæontology", in which "an attempt has been made to give a general account of the broad outlines of phylogenetic evolution". The author here deals with the more modern lines of research in the Palæontology of the Invertebrata, in a way which should arouse the interest of students. We think it would have been an advantage if this chapter had been expanded and fully illustrated, since this aspect of Palæontology has been less frequently dealt with in textbooks than the subjects of the other chapters.

REPORTS AND PROCEEDINGS.

British Association, Cardiff, 1920.

Section C.—Geology.

1. Presidential address by Dr. F. A. Bather, F.R.S. (see p. 473).

2. Professor A. Hubert Cox: Address on the Geology of the Cardiff District.

3. Dr. J. W. Evans, F.R.S.: The Origin of the Alkali Igneous Rocks.

These rocks, distinguished by unusually high proportion of alkalies, relatively to alumina and lime, occur mainly where the crust of the earth is thick, the heat-gradient low, and there has been no folding since remote times. Magmas appear to have reached surface by fault fissures from great depths where high pressures are associated with comparatively low temperatures. Crystallization proceeding under such circumstances, there would be an early formation of minerals with small molecular volumes, garnet, kyanite, epidote, and zoisite, minerals rich in lime and alumina. Zoisite may be regarded as high pressure representative of anorthite, but there is no corresponding representative of albite or orthoclase. Consequently we should expect a residual magma exceptionally rich in alkalies which would furnish material necessary for formation of alkali rocks.

4. Reports of Research Committees.

5. Joint meeting with Sections D and K. Discussion: Mendelism and Palæontology: The Factorial Interpretation of Gradual Changes, especially when New Characters appear late in the Individual Life-cycle. Dr. F. A. Bather, F.R.S.

The question posed. Can characters be regarded as independent, i.e. as manifestations of independent factors in the germ? Does evolution take place solely by addition or loss of such factors? Is there not also a gradual modification of the body, resulting in a continuous transition? Palæontologists find such transition to be the rule in those cases where the geological record is sufficiently complete. (See President's Address, Section C, heading "Continuity in Development".) Palæontologists support the theory of recapitulation, and believe that in many cases gradual modification of the adult and senile body is, in the course of race-history, pushed back to earlier growth stages. (See President's Address, Section C, heading "Recapitulation".) Can such cases be explained by independent factors in the germ? Does not that hypothesis involve, first, an alteration of the germ through change in the body, secondly the determination of that germinal change in a direction harmonious with bodily change?

Dr. R. Ruggles Gates:—

According to mutationist hypothesis, germinal characters arise as alterations of single elements of the germ plasm. This conception avoids the difficulties involved in considering the change as due to the loss or addition of a factor. It recognizes on the one hand the solidarity of the germ plasm as a whole, and on the other the independent origin of variations in its several parts. Such variations are termed karyogenetic, since they apparently arise in the nuclei and are perpetuated by miotic division. Mutations of this nature are almost universal amongst wild plants and animals, and some of them are so small that for general purposes they are practically continuous. They differ from the Darwinian conception of continuous variation, however, in that (i) they do not arise in any regular order, (ii) they are inherited as separate units. But recapitulation is an almost equally widespread phenomenon in animals, and to a less extent in plants. The recapitulation in animal embryos, and in such fossil groups as the Ammonites, implies the addition of terminal stages to the development of the organism. From the standpoint of organic structure this process is clearly different from a mutation by which the nuclear unit is modified throughout the organism. Recapitulatory characters thus fall into two groups: (i) embryonic, which appear always to imply adaptation of the organism to different conditions, and are best explained by the neo-Lamarckian principle; (ii) orthogenetic, which appear late in the life-cycle but are germinal in origin and non-adaptional.

Professor J. E. Duerden: Mendelism; Palæontology; Evolution.

Recent investigations in genetics in general give support to the factorial hypothesis, namely, that the characteristics of the body are represented in the germ plasm, in all probability in association with the chromosomes. Supporting evidence is forthcoming from sex, crossing-over and localisation. Any hereditary change in an organism must therefore be associated with factorial change in the germ plasm. Casual mutations readily admit of Mendelian interpretation, but evolution in general does not take place by changes of this kind. Evolution of species often seems to call for a similar change in the whole assemblage of individuals within an area, while palæontology and the study of numbers of related forms call for gradual successional changes in the same direction as regards any particular structure (orthogenesis). Mendelian experiments do not yet afford any great support for either of these demands. Observed mutational changes do not call for environmental influence, and are wholly apart from any adaptive considerations; natural selection plays no part in the origin or preservation of variations, but may be eliminative. It is highly questionable whether somatic or environmental influences can modify the germinal factors in definite directions, but disruptive changes and gradual loss of factorial vigour, or perhaps senility, may be contemplated, continued over long ages. As the common germ plasm of a race may at any one time be presumed to be in somewhat the same condition, evolutionary changes on somewhat similar lines may be expected.

Professor A. Dendy, F.R.S.

6. Dr. T. Franklin Sibly: The Old Red Sandstone of the Mitcheldean District, Gloucestershire.

Mitcheldean lies on the Gloucestershire–Herefordshire border 10 miles west of Gloucester, and in the latitude of the Breconshire Beacons. In this neighbourhood persistent westerly dips determine an outcrop of the whole of the Old Red Sandstone, with a thickness of some 7,500 feet, in a band scarcely 2 miles wide, bounded on the east by the Silurian strata of the May Hill anticline and on the west by the Carboniferous of the Forest of Dean coal-basin. The sequence of strata determined in this locality offers a possible key to the wilderness of Old Red Sandstone in Herefordshire.

7. Professor W. M. Flinders Petrie, F.R.S.: The Continuance of Life on the Earth.

If by any process of aggregation the earth has been at a red heat, all the lime and soda would be combined with the silica (now sandstone) and all the carbonic and hydrochloric acids would be in the atmosphere (now locked up in limestone and salt). The changes from that condition would consist in the acids gradually decomposing the silicates; at present there is only a minute fraction of the original carbonic acid left in the atmosphere. The decomposition of a few more inches of silicates over the globe will exhaust the carbonic acid, and life could not exist. This may take place in a few hundred thousand years, and such is the limit to vegetable and therefore to animal life, irrespective of solar cooling. The amount of carbon in the strata is probably enough to combine with all the oxygen of the air; hence, land-breathing animals were impossible until after the carbon had become separated and left oxygen free. This agrees with the appearance of air breathers after the Carboniferous age.

8. Dr. A. E. Trueman: The Liassic Rocks of Somersetshire and their Correlation.

The Liassic rocks of Somerset are thin but richly fossiliferous, yielding many large Ammonites. When followed towards the Mendips there is considerable reduction in thickness and marked lithological change. At several localities a white limestone resembling the Sutton Stone of Glamorgan is seen to rest on the Carboniferous Limestone; it is developed at various horizons, and usually contains no Ammonites, but correlation can be made by means of species of *Ostrea* and *Gryphea*. In the numerous exposures near Radstock many non-sequences can be located, and maps showing the movement of intra-Liassic folds have been prepared.

9. Dr. J. K. Charlesworth: The Glaciation of the North-West of Ireland.

The major part of the region investigated, including the Donegal Highlands and the Sperrin Mountains, was never invaded by the Scottish ice as currently supposed, but the Donegal mountains, in particular the Barnesmore Hills, formed a most powerful centre of radiation, whence ice streamed westwards to the Atlantic and eastwards over the Sperrin Mountains to Cookstown and beyond. In a south-easterly direction the ice passed obliquely across the Clogher Valley in Slieve Beagh to the Central Plain of Ireland, where was located the "central axis" of Hull and Kilroe. This axis of dispersal existed at no period of the glaciation.

10. Mr. L. Dudley Stamp: On Cycles of Sedimentation in the Eocene Strata of the Anglo-French–Belgian Basin.

The Eocene deposits of the great Anglo-Franco–Belgian Basin can be grouped naturally into a series of cycles of sedimentation—the Montian, Landenian, Ypresian, Lutetian, Ledian, and Bartonian. Each cycle commences with a marine invasion and passes from marine to estuarine and continental conditions. In England the changes are closely connected with the gentle, intermittent uprise of the Weald.

11. Dr. J. W. Evans, F.R.S.: The Geological Structure of North Devon.

In early Permian times the Devonian and Carboniferous were thrown by pressure from the south into overfolds, with overthrust faults. A subsequent relaxation of pressure resulted in a slip back on the same fault-planes. There were also oblique tear-faults striking between north and west. A mountain region then sloped southward from the Welsh Coast to Mid-Devon and much material was transported in that direction. In the Triassic period, however, the Palæozoic had, as a whole, its present contours, including the great Glastonbury and Bristol Channel depression descending to the west, and its subsidiary valleys still partly filled with Mesozoic deposits. In Tertiary times there was renewed pressure from the south. This met with less resistance in the west, and there was consequently a relatively forward and downward movement on that side along the old tear-faults and possibly new fractures with the same general direction. In Pliocene times the land was more submerged than now, and the subsequent emergence seems to have continued in most places till a comparatively recent date.

12. Professor W. L. Bragg: Crystal Structure.

The investigation into crystal structure, which has been made feasible by the discovery of the diffraction of X-rays by crystals, has led to a determination of the precise positions of the atoms in a number of the simpler crystalline forms. Recent theories of atomic structure such as those put forward by Bom and Lande, Debye, Lewis, and Langmuir, are largely based on the arrangement of the atoms in crystalline solids, since this arrangement affords an insight into the nature of the forces acting between the atoms. In such compounds as sodium chloride, it is probable that the atoms exist as ions of sodium and chlorine, and that the crystal is held together by the electrostatic attractions of these ions, thus accounting for the fact that there is no grouping of the atoms into molecules in the solid. In other compounds, such as those of two electronegative elements, the molecular arrangement persists in the solid state and the chemical combination appears to be of a different type from that of sodium chloride. A consideration of the distances between the atomic centres in crystals supports the conception of the two types of chemical combination.

13. Mr. DAVID DAVIES: Palæontology of the Westphalian and lower part of the Staffordian Series of the Coal-measures as found at Clydach Vale and Gilfach Goch, East Glamorgan.

Recorded: 45,000 plants; 1,000 shells; two insects and one fish scale. Plants yielded 154 species, shells six species, insects two species, fish scale one; forty-five of these are new to South Wales and seven new to Britain. Ecology of ten horizons: Equisetales predominate in four, Filicales and Pteridosperms in three, Lycopods in two, and Cordaitales in one horizon. When Lycopods predominate, Fern and Fern-like plants are weak, and vice versa. 37 per cent plants are common to both series; 31 per cent distinctly Staffordian; 32 per cent distinctly Westphalian. The Pennant Sandstone produced smooth round coal pebbles, giving evidence of a geological break. A significant feature is the appearance of new species at this period.

14. Mr. D. C. EVANS: The Ordovician of Carmarthen.

This paper dealt with the stratigraphical succession and tectonic structures of the Ordovician rocks of Carmarthenshire.

PRESIDENTIAL ADDRESS TO SECTION C (GEOLOGY).

Owing to unusual pressure on our space we are unable this year to reprint the President's address in full. For the following abstract and appreciation we are indebted to Dr. F. H. A. Marshall, F.R.S.

Dr. Bather's presidential address deals with the fundamental principles of Palæontology. He begins by pointing out that it is the time-concept which characterizes the subject and raises it above the mere description of extinct assemblages of animals and plants, and he proceeds to consider the effect of this concept on the principles of classification and on the ideas of relationship. In the light of palæontological study definitions of groups of animals or plants can no longer be purely descriptive; they must take account of ancestry and succession in time. As Dr. Bather expresses it: "The old form of diagnosis was *per genus et differentiam.* The new form in *per proavum et modificationem.*" It has not been unusual to fall into the error that the apparent succession through a series of strata of similar forms of life implies descent, and Huxley, in his scheme of equine evolution, regarded *Palæotherium* as being in the line of direct ancestry of the modern horse. However, this species, and the later *Architherium*, have been shown by Professor Osborn and his co-writers to belong to side-lines of descent. Occasionally an apparent succession is due to immigration of a distant relative from another region in the manner supposed by Cuvier in seeking to account for the renewal of life when an earlier fauna had disappeared. Dr. Bather goes on to consider the evidence of descent afforded by palæontological instances of the law of recapitulation, which is so well illustrated by the ammonites. In the next section of the address he points out that the "line upon line" method is the only absolutely safe way of advance in Palæontology, for mutation must be affiliated with mutation and species with species; the investigator must work his way back, "literally inch by inch through a single small group of strata," if he wants to be sure of his conclusions about lines of evolution. Concerning the question as to whether descent had taken place by continuous or discontinuous variation it is shown that contrary to what might have been expected, palæontological opinion is emphatically in favour of the former view. With the species of the sea-urchin *Micraster* the changes undergone in the course of ages were apparently gradual in all the different characters, and many other instances of continuous evolution might be given. After brief references to the concepts of seriation or the direction of change, Dr. Bather proceeds to discuss the question of pre-determination, which many palæontologists seem to have accepted. The principle is thus expressed: "A race once started on a certain course will persist in that course; no matter how conditions may change, no matter how hurtful to the individual its own changes may be, progressive or retrogressive, up hill and down hill, straight as a Roman road, it will go on to that appointed end." The principle is allied to Driesch's concept of entelechy in ontogenetic development, and the question of its validity seems to be part of the wider problem as to whether teleological categories have any place in biological thought, a question which is answered in the negative by all men of science, excepting the small minority who adopt the attitude of Dr. J. S. Haldane. Dr. Bather next discusses adaptive evolutional "convergence" and passes on to consider Dollo's so-called law of irreversible evolution. He does well to insist that this law is a statement of observed fact, and, understood rightly, need not imply any inherent principle affirming the impossibility of reversal. The next sections deal with the "study of habitat" and "the tempo of evolution", which, it is shown, is variable, depending on changes in the outer conditions. This is illustrated by the comparative study of the development of whales, sirenians, and horses during the Tertiary period, the rate of evolution of these three groups varying with that of changes in the nature of the food. Thus the sirenians underwent a slow change because they retained the habit of feeding on soft water-plants, the horses developed more rapidly in correlation with their taking to the plains and becoming eaters of grain, while the whales, though at first their development was slow, from the Oligocene onwards changed with extraordinary celerity as they adopted and diversified new habits of feeding and living. In referring to the "rhythm of life", Dr. Bather concludes that the phenomenon must reflect the great rhythmic waves that have uplifted the mountains and lowered the deeps, as well as the smaller waves and ripples that have from time to time diversified the face of the earth. The address is throughout both suggestive and stimulating. It concludes on a note of sanguine anticipation for the future.

F. H. A. M.

CORRESPONDENCE.

FLINT PROBLEMS.

Sir,—All efforts to solve the problems of flint formation are likely to be unsuccessful unless we marshal all known facts and deal with them seriatim. At present I doubt if it is possible to give even a satisfactory definition of flint!

Many years ago I found flint at Margate and Studland Bay, which is clearly silicified chalk. In places silicification has not been completed, and these softer parts have been removed, leaving cavities. Near Corfe I came across nodules in the chalk which, with the exception of a thin external crust of flint, are entirely composed of soft, white cryptocrystalline silica. There are flint pebbles at Boscombe and Southbourne-on-Sea that are composed partly of the same cryptocrystalline silica[1] and partly of chalcedonic

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[1] *Nature*, May 1, 1890.

and opaline silica. On Chesil Beach there are pebbles which appear to be nothing more or less than indurated colloid silica.

Again, we have at Rottingdean, Walmer, and other places, examples of flint filling up cracks and fissures in chalk that was evidently ex-marine at the time. In some places fractured flints have been repaired by such secondary precipitations of silica, in others (Freshwater) there has been no such reparation in the crushed flints, but at Alum Bay silicate of iron has acted as a cementing medium. At Corfe, though the conditions appear to be the same, I have found the cracks of crushed flints filled with calcite.

Near Faversham there are compound flint nodules, flints within flints—as many as four or five, formed one around the other, with evidence of a periodic cessation of the process of aggregation between each.[1] It is difficult to understand how such processes could operate either in ex-marine chalk or submarine ooze. Again, why are so many flint nodules hollow when they contain fossils? Did the gases of decomposition cause expansion before the silica became completely "set"? Why are cavities so often lined with crystalline quartz when fossils, or parts, are present, and with chalcedony when they are absent? I have frequently noticed this.

Our ignorance of the chemical and physical conditions prevailing at the bottom of the old chalk sea renders the work of the flintist very difficult. What do we know in reference to the pressure, temperature, and composition of the water at that time? Supposing flint existed originally in a colloid state on the sea-bed, then the sponges and other organisms, so often associated with flint, must have existed there too. But this postulates a hard bottom upon which such things would rest, not a soft one into which they would all sink and become buried in ooze. A friend of mine has a flint nodule from the chalk which has been formed around a piece of teredo-bored wood, and another example of a nodule with a nucleus of silicified wood may be seen in the Museum at Dover. Now, did these pieces of wood sink some 2,000 fathoms to the chalk ooze, and then become surrounded with colloid silica, which subsequently became flint? If not, did they, then, sink some depth into the ooze and become enveloped by it? If the latter, was the ooze surrounding the wood replaced by colloid silica, molecule for molecule, or was the ooze mechanically displaced by the colloid during its accrescence on the wood? If we cannot admit either of the foregoing we are driven to the conclusion that the silica was formed around the wood while suspended in the water. If objects suspended in water sink more slowly as the pressure increases, there might be time for the deposition of colloid silica around organisms before they reached their final resting-place in or on the ooze.

C. Carus-Wilson.

Strawberry Hill.
September 13, 1920.

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[1] *Nature*, June 28, 1917.

OBITUARY.

Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S.

BORN 1860. DIED JUNE 21, 1920.

DR. WHEELTON HIND was born at Roxeth, near Harrow, in 1860, and died after a comparatively short illness at Ashley, near Stoke-on-Trent, on June 21 of this year. He received his medical training at Guy's Hospital and London University, where he graduated M.D., and also gained the Fellowship of the Royal College of Surgeons. In 1884 he began practice in Stoke-on-Trent, and during the following thirty years established a reputation as one of the foremost surgeons in the district, being at the time of his death the senior member of the surgical staff of the North Staffordshire Infirmary.

So far as research work is concerned, Hind's interest in geology practically dates from his arrival in Stoke, for very shortly thereafter he made the first of a long series of contributions on local geology to the Transactions of the North Staffordshire Naturalists' Field Club. Amongst his earliest papers was one on the geology of Suffolk, which was incorporated in his father's book on the flora of that county. As might be expected from his location in a coal-mining district, most of his work related to the stratigraphy and palæontology of the Carboniferous rocks, especially of the lower members of that series. In an endeavour to find some key to the succession of these strata he soon extended his investigations to the corresponding rocks of Derbyshire, Lancashire, and Yorkshire, where he collaborated with Mr. J. A. Howe in a detailed examination of the Lower Carboniferous sequence of the Pendle Hill area. As a result of this work the hitherto recognized classification of this series underwent considerable modification by the recognition of the "Pendleside Series" of shales and thin limestones, with a characteristic fauna, as a group intermediate between the Carboniferous Limestone and the Millstone Grit and differing essentially, both in lithology and fossils, from the Yoredale Series. The development of this series in Derbyshire and Staffordshire was recognized, and it was also traced to the Isle of Man and Ireland.

The basis of Hind's stratigraphical work was the attempt to discover a series of life-zones by means of which the Carboniferous rocks could be subdivided and those in different districts correlated. For several years he acted as secretary of the British Association Committee on "Life-zones in the British Carboniferous Rocks", and not only collected assiduously himself but also identified much of the material obtained by others. The comparative lack of success in this work, so far as the Carboniferous Limestone is concerned, was possibly due to the fact that most of the collecting was done in the North Midland area, where continuous sequences are conspicuously absent. Even the results of Vaughan's brilliant researches in the Bristol district have not been found easy of application to the northern series, although much of Hind's subsequent work was directed towards that end.

By the discovery of Pendleside zone-fossils in the Culm measures of Devonshire, Hind was able to show that the lower portion of the latter was homotaxially equivalent to the former, while the goniatite fauna of the higher Culm strata confirms Arber's conclusion that they are of Middle Coal-measures age. Despite military duties entailed by the War—Hind went to France as Lieut.-Colonel in command of the North Midland Territorial R.G.A., and later occupied responsible hospital posts in various districts—he found time to elaborate the series of goniatite zones, ranging from the *Posidonomya Becheri* zone of the Pendleside up to the Middle Coal-measures, which he had formulated in 1909, and, in conjunction with Dr. A. Wilmore, to apply them in a detailed re-examination of the Clitheroe district.

At an early stage in his work he recognized the necessity for a reinvestigation of the Carboniferous mollusca, and the fruits of this appeared in the form of three monographs on the lamellibranchs. In conjunction with Mr. J. T. Stobbs a chart was drawn up in which these fossils, especially the freshwater species, were utilized in the establishment of horizons in the North Staffordshire Coalfield. Hind also published an important paper on the molluscan fauna of the Scottish Millstone Grit, and recognized the relationship to the fauna of homotaxially higher beds in America and Russia. His most important palæontological work relating to rocks other than the Carboniferous was his description of the Silurian Lamellibranchs in Mrs. Gray's Girvan collection.

Elected a member of the Geological Society of London in 1891, he received the Lyell award in 1902 and the Lyell medal in 1917. He was also an honorary member of the Société Géologique de Belgique, as well as of several British Societies. When it is remembered that his geological work was done in such time as could be snatched from a busy professional life, one marvels that so much was achieved. In a period of thirty years, some four of which were spent on war service, his published papers numbered over eighty, while in addition his services in the identification of fossils were largely utilized by the Geological Survey as well as by private workers. Such an output was only rendered possible by his wonderful vigour and enthusiasm. Whatever the verdict of the future regarding the details of his work, Hind will be remembered as one of the pioneers in the elucidation of the relationships of the Carboniferous rocks.

A. S.

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NOVEMBER, 1920.

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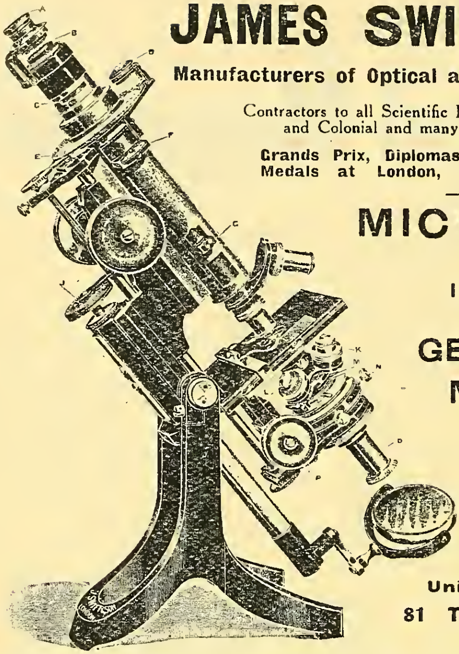

THE
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EDITORIAL NOTES.

THE Swiney Lectures for 1920 in connexion with the British Museum (Natural History) will be delivered by J. D. Falconer, M.A., D.Sc., F.R.S.E., etc., on Mondays, Wednesdays, and Fridays from November 8 to December 3 at 5.30 p.m. in the Geology Lecture Theatre, Royal School of Mines, Prince Consort Road, South Kensington. The subject of the lectures, which will be illustrated by lantern slides, is "The Modelling of the Earth's Crust". Admission is free.

* * * * * *

On November 7 Professor Alfred Gabriel Nathorst, of Stockholm, will celebrate his 70th birthday. In many fields Nathorst has left a deep imprint on our science. As a specialist he ranks among the most eminent of palæobotanists, for his scientific results, for his invention of new methods, and for the large and admirably arranged collection that he has established in the Swedish State Museum. As a pupil and follower of Linnarsson his early studies were largely on the Palæozoic rocks of Southern Sweden, where the curious markings in the Eophyton sandstones led to his classical memoir on the origin of such tracks. His familiarity with the rocks in the field, with their fossils in the laboratory, and with the writings of his predecessors in the library rendered him the most appropriate author of that useful work *Sveriges Geologi*. His love of sport (to which the deafness of his later years is due) fitted him to lead those exploring expeditions to Spitsbergen and Greenland which have maintained the high place already gained by Sweden in geographical research. British geologists, who are proud to greet Professor Nathorst as almost the senior Foreign Member of the Geological Society of London, will send him their congratulations on achieving three-score years and ten of vigorous and fruitful life.

* * * * *

Mr. R. Bullen Newton, F.G.S., lately retired (under age-limit) from the Geological Department in the British Museum (Natural History), has gone upon an expedition to Trinidad to examine the fossiliferous deposits yielding petroleum in that island. These beds were noticed in the GEOLOGICAL MAGAZINE by the late R. J. Lechmere Guppy (see GEOL. MAG. 1865, p. 256; 1866, p. 179; 1870, p. 235; 1874, pp. 404–33; 1892, p. 331; 1900, p. 322), and of late years have attracted much attention.

* * * * *

STANLEY SMITH, M.A., D.Sc., has been appointed Reader in Geology in the University of London (Bedford College) in place of Miss C. A. Raisin, D.Sc., who has resigned.

* * * * *

THE "David Syme" prize of £100, with medal, for scientific research for the year 1920, has been awarded to Mr. Frederick Chapman, A.L.S., palæontologist to the National Museum and lecturer in palæontology in the University of Melbourne.

* * * * *

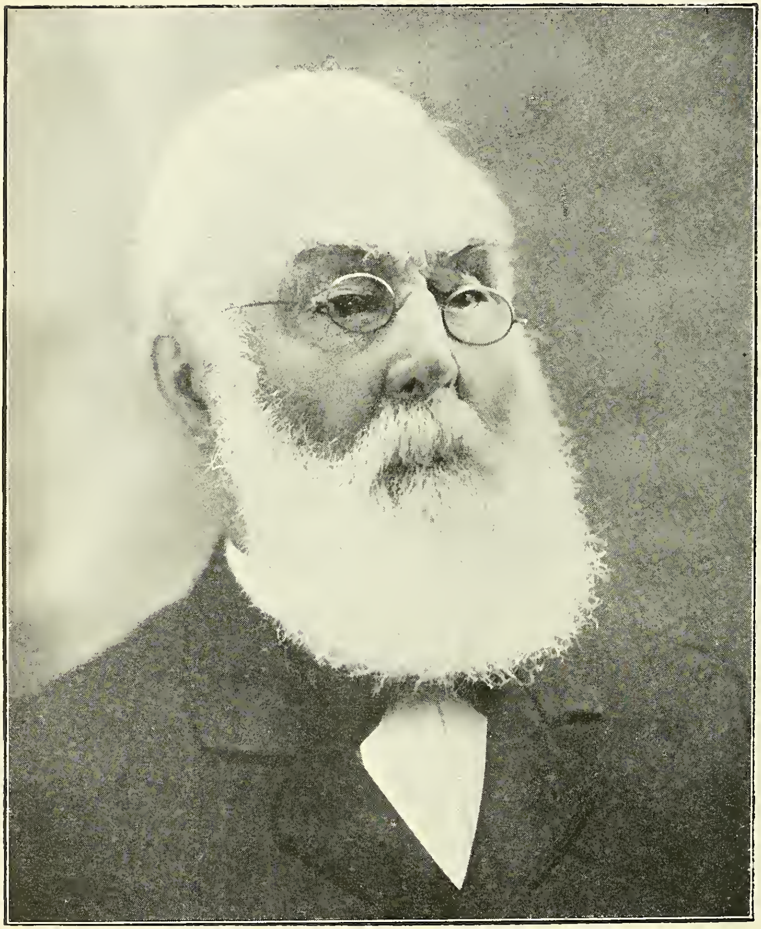
DR. GRIFFITH TAYLOR has been appointed to the newly established professorship of geography in the University of Sydney. After graduating at Sydney Dr. Taylor became a research student of Emmanuel College, Cambridge, and was afterwards chief geologist in Captain Scott's Antarctic expedition. Since then he has been connected with the Federal Meteorology Bureau in Melbourne.

* * * * *

A FREQUENT contributor to the GEOLOGICAL MAGAZINE, Dr. Arthur Holmes, Assoc.R.C.Sci., F.G.S., Imp. Coll. Sci. Tech., sailed for Burma in September last for several months (on leave) to carry on geological investigations in that region as to oil and other economics.

* * * * *

AT the present day good exposures of the Cambridge Greensand are seldom seen, but an excellent opportunity of studying this interesting deposit is now to be found at the Norman Cement Works, near Cambridge. The company works the lower part of the Chalk Marl for cement, and excavations are usually carried down to a few feet above the Gault. Some new plant is now being installed in the pit, requiring considerable excavation for foundations. The base of the Chalk Marl and the Cambridge Greensand have been dug through and about 5 feet of Gault is exposed. There is, therefore, an excellent clean-cut section showing the Cambridge Greensand, and its relation to the beds above and below. The pockety surface of the Gault, bored by animals living in the Greensand sea, is well seen, since the burrows are filled with a light greyish-green sand, contrasting well with the darker Gault. The phosphatic nodules characteristic of the bed are well developed, and the gradual passage upward into the Cenomanian is clear. No doubt the Manager of the Company would be pleased to allow any geologist interested in this bed to visit the pit while this excellent temporary section is exposed.



James Hall

A great American Geologist of the last Century.[1]

PROFESSOR JAMES HALL (1811–98).

(PLATE X.)

JAMES HALL'S active career in American geology extended over sixty-two years of uninterrupted official connexion with the State of New York, a record which stands unsurpassed in the history of official science. At the age of 25 Hall entered the geological service of New York upon the organization of the Natural History Survey in 1836, and his service was terminated by death in 1898, at the age of 87 years. So great was the span of his life that it not only covered but formed in itself a large share of the evolution of geological science in America. James Hall's enthusiasm for his work never diminished. His death was but the incident of a day, and his life, even to that day, was inspired by the undivided purpose to develop and advance his science. Such a life could not fail to be immensely productive, and his was rich in its output from the publication of his first great quarto report on the Geology of the Fourth District of New York (1843) to the last of the thirteen quarto volumes of the Palæontology of New York.

When the Natural History Survey was organized Hall entered upon it for the first field season in 1837, as an assistant to Dr. Ebenezer Emmons, in the crystalline rock region of the Adirondack Mountains. The second year found him in charge of the "Fourth District" of western New York, then a sparsely settled and still heavily timbered region. Here he gradually unfolded the beautifully ordered succession of the Palæozoic rocks with their wealth of fossil life, and it was their richness in fossils that gave birth to his desire and purpose to describe and figure them, and with them to verify and establish the classification of the "New York Formations" as set forth by the conclusions of his colleagues on the State Survey.

No provision had been made for such a study of the fossils in the original plans of the Survey; when, therefore, the time arrived that the work was officially concluded in 1843, Hall succeeded in obtaining the sanction of the State, and was himself commissioned to prosecute this work and prepare a report on the Palæontology of New York, which was to be in one volume and to be completed in one year. The volume actually occupied three years, and was followed by twelve more volumes, under the title of *The Palæontology of New York* (which appeared successively in a period of more than half a century). The work is still going on vigorously. The "New

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[1] A brief obituary of Professor James Hall, For. Memb. Geol. Soc. Lond. 1848, appeared in the GEOL. MAG. for September, 1898, pp. 341–2. By the kindness of his successor, Professor John M. Clarke, LL.D., For. Corr. Geol. Soc. Lond., we are enabled this month to publish some additional notes of our old friend and fellow-worker, together with an excellent portrait.

York Series of Geological Formations", as set forth by the four State Geologists, elicited Hall's ardent support in all his descriptive work upon the fossils of these formations. Some of its terms antedated those now in common acceptance; thus, "Champlain" was an earlier and better defined name than Ordovician or Lower Silurian; Erian an earlier and more clearly defined term than Devonian; and on the basis of priority of fossil evidence the term "Taconic", of Emmons (though this was fought over for two generations and not highly regarded by the New York geologists), has on the basis of its fossils a chronologic right of way over the name Cambrian. It was only very slowly and with obvious reluctance that Hall yielded to the personal arguments of Murchison in adopting the term Silurian for the terms in the series that are now commonly or provisionally grouped under the name Ordovician, and it is very interesting to a student of the development of geological ideas in America to see how these now commonly accepted divisions of the lower rocks had to struggle for recognition in this part of the Western Hemisphere.

The adoption, on *palæontological* grounds, by the late James Hall and other American geologists of the common English (and European) names for the divisions of the Palæozoic rocks, has been already attended with the most splendid results, and if carried out (internationally) by the authors of our textbooks and the professors in our colleges will enable us to synchronize all the great geological formations of the globe.

Hall was born and spent his boyhood along the coast of Eastern Massachusetts, and acquainted himself with the marine life of those shores as well as a boy could do who had no books or teachers. He walked from his home at Hingham, Mass., a distance of 200 miles, to attend the Rensselaer School at Troy, not far from Albany, N.Y., and his knowledge of the common life of the sea and his wide acquaintance with botany were always put to their ultimate service in his reconstruction of the extinct life of the Palæozoic rocks. His work was of necessity largely descriptive, as he was engaged in the portrayal of the succession of fossil faunas as a pioneer in a virtually unknown field. All students of his books will bear testimony to the accuracy and fidelity of his work, and the volumes of his early years are still as essential to the study of the Palæozoic faunas of America as the works of Murchison to a knowledge of the "Silurian System". Through his impressive personality, his unrestrained vigour, and his ability to convince persons in authority that he was in dead earnest, Hall was enabled to keep his palæontological work generously supported by the State of New York, even when other departments of science were languishing for public support. But he did all this much as St. Paul carried on his missionary endeavours; he was often in trouble, and not infrequently had to fight the wild beasts at court who thought his preaching foolishness.

Incidentally to his other work, Hall did many fine pieces of closely analytical morphology, which were in large measure the product of his own studies. He had also a keen appreciation of the necessity of making his work intelligible to students by the excellence and accuracy of his illustrations; to secure this he drew his draughtsmen and illustrators, his lithographers and pressmen, from various quarters of the world, and carried out the printing under his own eye and within easy reach of his own laboratory. A word is appropriate in regard to Hall's laboratory. In the early fifties he established himself and his collections in a building that he had specially arranged for the prosecution of his work, and then began to gather about him men who were to assist him in the working out of the ever-accumulating materials for his great undertaking. In this laboratory there entered, and in due time emerged, a long line of assistants who afterwards acquired an established place in American geological science. Among these were Fielding B. Meek, Robert P. Whitfield, Ferdinand V. Hayden, Charles A. White, Charles D. Walcott, Charles E. Beecher, John M. Clarke, Charles Schuchert, and a number of others. The old laboratory still stands and has happily been set aside by the city of Albany as a place not to be effaced, and it bears upon it a commemorative tablet attached thereto by the Association of American Geologists.

Mr. Hall was naturally not content with activities confined to the State of New York. He had a colossal capacity for work, and was at one and the same time during the later fifties State Geologist of Iowa, State Geologist of Wisconsin, in active association with Sir William Logan on the Canadian Survey, and also prosecuting the work in New York. It was in these busy years that, as President of the American Association for the Advancement of Science, he prepared and delivered his most philosophical discussion on a geological theme, "The Origin of the North American Continent." In this he set forth an entirely new explanation of mountain building, which is still highly regarded, especially by the French geologists, under the designation of the Law of James Hall. While very seriously engaged in these undertakings, almost every State in the Union, as it proceeded towards the organization of a geological survey, made proposals for his services. Hall, however, really cared for this outside work only in so far as he could touch its fossils, and it is because he ignored reports and turned all his efforts to an exposition of the fossils that the support of Iowa and Wisconsin was finally withdrawn. Naturally, in his later years, though with many imperative interests, he became more and more dependent upon his assistants for the preparation of his great volumes.

There are few left who still remember the singular combination of traits that this remarkable man presented. He was gentle, affectionate, and confiding; on the other hand, he was suspicious, irascible, and imperious, and such a contradictory combination of qualities required patience and careful adjustment on the part of his associates. For fifteen or twenty years Hall was much engaged with the organization of the International Congress of Geologists, which originated from a convocation of geologists held in Buffalo, N.Y., in 1876. Hall was chairman of the organizing committee and was chairman of the first congress that met in Paris under the presidency of Professor Hebert. He followed the congresses eagerly at their subsequent sessions, and at the age of 86 he went with his daughter to Europe, passing through England and visiting the British Museum (Natural History) on his way to St. Petersburg to attend the session of that year, and going even so far afield as the Caucasus Mountains. This last great experience in his life was something of a triumphal progress, for he was venerable not only in years but in experience, and carried with him a most impressive personality. His strong vigorous body, his head adorned by snow-white hair and flowing beard, and his cheeks, even at that age, bearing the ruddy tints of vigorous health, did not fail to attract attention wherever he went, and his tour through Russia and the states of Europe commanded wide attention.

James Hall has left an indelible stamp upon the history of American geology. The time will never come when his work can be laid aside as no longer of service or needed in aid of the progress of geological knowledge. What he did was fundamental, and the superstructure which his successors have laboured to raise can rest securely upon his foundations. Hall was naturally much honoured by scientific societies and by the bestowal of many orders and decorations. He became a Foreign Member of the Geological Society of London in 1848.

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Encouraged by such early pioneers as James Hall and his contemporaries, a host of modern palæontologists have boldly sailed into those little-known seas of past geologic time, and have discovered new lands and new faunas and floras, adding vastly to our knowledge of the buried past, furnishing at the same time reliable landmarks for the stratigraphical worker, and thus transforming geology from a dead into a living science.

ORIGINAL ARTICLES.

The Quartzose Conglomerate at Caldon Low, Staffordshire.

By J. Wilfrid Jackson, F.G.S., and J. Kaye Charlesworth, M.Sc., Ph.D.

IN the Geological Magazine for February, 1919 (pp. 59–64), one of the present writers, in collaboration with W. E. Alkins, described an exposure of a quartzose conglomerate on the north-west flank of Caldon Low. The conclusions arrived at in that paper were adversely criticized by F. Barke, Wheelton Hind, and A. Scott in a later paper in the same Magazine.[1] These writers maintain that the conglomerate was not a contemporaneous deposit, but an assemblage of materials, analogous to that seen in the Weaver Sand-pits, south of the Ribden Mine, about one and a quarter miles away, which had filled up a solution cavity in the limestone and had become consolidated by the percolation of calcareous matter.

The present paper is written with the object of refuting the statements made by these writers as to the mode of origin and the age of the conglomerate. During the last twelve months quarrying operations have revealed tectonic features which clearly prove that the quartzose conglomerate is a true " intra-formational conglomerate ", as suggested in the original paper.[2]

To clear the ground it will be convenient to give a short description of the Weaver Sand-pits.

The Weaver Sand-pits.—The deposits in these pits consist chiefly of incoherent sands, clays, and pebbles, and closely resemble those of the series of pockets in the limestone of the high ground of Derbyshire from Parsley Hay to Wirksworth. The principal pit in the Weaver series, and the one now working, differs from the adjacent ones and from the Derbyshire pits in containing blocks of hard sandstone, with and without pebbles, which are obviously residual Bunter beds. These blocks are erroneously regarded by Messrs. Barke, Hind, and Scott as due to the consolidation of part of the contents of this pit.[3] They further state that they are similar lithologically to the infilling at Caldon Low. The remains of a similar sand-pit are still to be seen close to the road to Cauldon village, 1 mile N.N.W. of the Weaver pits, and a quarter of a mile S.W. of the quartzose conglomerate under discussion. In this pit a block of black Pendleside shale, containing *Posidoniella minor*, was found by J. Allen Howe, and duly recorded in his paper, " Notes on the Pockets of Sand and Clay in the Limestone of Derbyshire and Staffordshire." [4]

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[1] Geol. Mag., Vol. LVII, 1920, p. 76.

[2] Ibid., Vol. LVI, 1919, pp. 59–64.

[3] Ibid., Vol. LVII, 1920, p. 81.

[4] Trans. North Staffs Field Club, vol. xxxi, 1897, p. 144.

Mr. Howe also noted the occurrence of large blocks of sandstone lying in the pit, which he was inclined at the time to regard as the remains of an outlying extension of the Bunter or Keuper beds.[1] Many of these blocks, some containing pebbles, are still to be seen here. Traces of other deposits of sand and pebbles are still visible in this neighbourhood, especially to the S. and S.E. of Milk Hill, near Waterhouses.

The presence of black shale in these pits is not peculiar to the Staffordshire series, as we have noted its occurrence in the Longcliff Pit, and in one near Parsley Hay, Derbyshire. In both cases the shale was well-bedded and in a vertical position, as if it had dropped in bodily. In the latter locality the shale contained *Posidoniella* and obscure plant remains.

That the whole series of these pits, both in Derbyshire and in Staffordshire, is pre-Glacial in age is clearly proved by the presence of Glacial Drift overlying them. During our survey of the pits recently we made a careful examination of the overburden in every case, and found that it was sharply marked off from the underlying sands and gravels, especially in the Derbyshire series. At one of the pits at Parsley Hay we obtained a large boulder of Eskdale granite and two of Borrowdale ash from the overburden, thus proving it to be Drift of the Irish Sea ice-sheet. At the Washmere Pit, near Newhaven, the same Drift contained ice-scratched boulders of dolerite, Carboniferous Limestone, and sandstone. The Drift overlying the disused pit at Minning Low yielded chert, Magnesian Limestone, dolerites, grits, etc. A dolerite boulder was also found in the Drift at the Longcliff Pit, while from the Drift at the working pit at Ribden we obtained a large ice-scratched boulder of gritstone. The presence of Boulder-clay here has long been known, and was described by G. Maw in 1867.[2]

The Quartzose Conglomerate.—In the earlier paper [3] it was pointed out that the condition of the section exposed in September, 1918, rendered the relation of the conglomerate to the massive Caldon Low limestones (*Humerosus* beds) somewhat doubtful, but the available evidence suggested an unconformity or a fault. Recent quarrying has revealed a slickensided surface running W.S.W.–E.N.E. along the truncated ends of the horizontal *Humerosus* beds, thus suggesting movement of the quartzose conglomerate and associated beds in a more or less horizontal direction.[4] Blocks of the conglomerate also show the same slickensided surface. It is clear from this fact that the conglomerate does not occupy its original position.

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[1] Ibid., p. 149.

[2] Geol. Mag., Vol. IV, 1867, p. 250, Fig. 7.

[3] Ibid., Vol. LVI, 1919, p. 60.

[4] This fault is probably the continuation of the mineral vein marked on the 1 in. Geological Map, No. 72, N.E. The vein is now destroyed by quarrying operations.

In their paper on the subject,[1] Messrs. Barke, Hind, and Scott give a diagrammatic section (E.–W.) of the quartzose conglomerate and adjacent limestones at Caldon Low. This shows to the west a basin-like mass of conglomerate occupying a hollow in the limestone, while towards the east two vertical pipes of conglomerate are shown leading down to two bands of the same material, one of which connects with the main mass of conglomerate in the cavity. This band is shown transgressing other beds in the section. It is suggested by these writers "that the conglomerate fills a subterranean hole in the limestone, probably formed by solution, the thin bands representing several underground watercourses leading into the main hollow" (op. cit., p. 78). We have been unable to find any evidence to justify this interpretation. On close examination in the field it is seen that the beds shown to the east of the main mass of conglomerate are, in fact, a series of impure limestones exhibiting current structures. They consist of alternating beds of sandy and pebbly limestones, lenticular quartz conglomerate, and beds composed of fragmentary shells of brachiopods and crinoid debris with included sand grains, the whole dipping N.N.W. at an angle of 30 degrees. The amount of sandy and pebbly detritus varies somewhat in beds on the same stratigraphical horizon, this having been doubtless brought about by changes in the currents bringing in the material. It is plainly seen that these limestones are the marginal deposits of the coarser conglomerate, which, in our opinion, fills an old channel. The top of this section, immediately under the surface soil, consists of a fairly thick bed crowded with crinoid-stems resting conformably on the conglomeratic beds.

From the foregoing description it will be seen that the idea of the existence of pipes from the surface is founded on a misinterpretation of the facts. The presence of large quantities of sand-grains and quartz-pebbles disseminated in beds of shelly limestones, etc., throughout this section militates against any such idea as piping.

Lower down the slope of the hill, and a little to the west of the section just described, the quartzose conglomerate is to be seen in the face of a low ridge running approximately E.N.E.–W.S.W., bounding the railway siding. The height of the section here, from the quarry platform to the surface of the ground, is about 28 feet. At the E.N.E. end a bed of crinoidal limestone, probably a continuation of the one seen at the top of the higher section, rests conformably on the quartzose conglomerate which extends vertically below the floor of the quarry. The conglomerate exhibits obscure bedding in parts, some of the beds being lenticular. On the W.S.W. side the conglomerate rests unconformably against limestones dipping about 26 degrees N.W. The field relations suggest that the irregular junction here is original, and that it represents the flank of the channel eroded in these limestones. The precise age of the flanking

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[1] Geol. Mag., Vol. LVII, 1920, p. 78.

limestones is not altogether clear; they are later than the Caldon *Humerosus* beds, and are faulted down along with the quartzose conglomerate. They appear to us to represent a portion of the upper part of the *Lonsdalia* subzone, and to be related to the fossiliferous limestones of the churchyard at Cauldon to the north,[1] which are almost certainly upper D_2. The somewhat similar faulted block of fossiliferous limestones opposite the Red Lion Inn, about half a mile south, is probably of the same age.

The horizon of the *Humerosus* beds of Caldon Low has been the subject of some dispute during recent years. In 1908 [2] they were tentatively assigned by Dr. Sibly to the upper part of the Lower *Dibunophyllum* zone, D_1. This position received strong confirmation in 1918 by Mr. L. M. Parsons' researches in Leicestershire (at Breedon Cloud and Breedon-on-the-Hill).[3] Other workers, including the late Dr. Wheelton Hind,[4] have definitely assigned them to the base of the Visean, viz. C-S_1. A full discussion of this important problem cannot be entered upon here, but must be reserved for a future paper dealing with the horizon of the *Humerosus* beds of Dove Dale. A preliminary article on this area, by one of the present writers, has already appeared in this Magazine.[5] The Dove Dale limestones are of the "Brachiopod Bed" type, and their faunal characteristics suggest that their stratigraphical horizon is nearer D_2 than D_1. We are inclined to regard the Caldon Low limestones with *Productus humerosus* as a more normal, but less fossiliferous, development of the Dove Dale series. The species at Caldon is not common throughout, but occurs only in well-defined beds, associated with a few other fossils, including two or three interesting forms of corals, which require further study.

Petrography of the Conglomerate.—Want of space prevents a lengthy discussion of the various constituents of the quartzose conglomerate, but readers are referred to the paper published in February, 1919 (op. cit., p. 60), for the main details. The whole assemblage, in our opinion, contains nothing of later date than the Carboniferous Limestone.

As pointed out in the earlier paper (op. cit., pp. 62–3), a rolled-shell and limestone-pebble conglomerate forms a striking feature along the boundary of the Midland Limestone massif on its north-western and western sides. In places this conglomerate contains a fair amount of well-rounded quartz, some pebbles being of large size.[6] From closer study of this marginal feature we have no

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[1] Geol. Mag., Vol. LVI, 1919, pp. 61–2.

[2] Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 44.

[3] Ibid., vol. lxxiii, 1918, pp. 94–100.

[4] Geol. Mag., vol. LV, 1918, p. 480; Vol. LVII, 1920, p. 78.

[5] Ibid., Vol. LVI, 1919, pp. 507–9; see also Sibly, ibid., Vol. LVII, 1920, pp. 20–2.

[6] We have seen specimens in W. F. Holroyd's collection and possess others from similar beds near Wetton, Staffs. See also Trans. Manch. Geol. Soc., vol. xxv, 1896, pp. 124–5.

hesitation in correlating the Caldon quartzose conglomerate with it, and in assigning the whole series to the *Cyathaxonia* subzone D_3. The same horizon is represented by the series of limestones in the small quarries near Field House, north of Waterhouses.[1] In some of the beds here quartz pebbles and grains occur associated with rolled and broken shells, pebbles of limestone, fish-teeth, crinoid debris, and corals (several forms). Some of the brachiopod shells and corals are beekized, and stand out in relief on joint faces. We are also of the opinion that the greater part, if not the whole, of the series of limestones and rolled shell-beds exposed in the quarries at Waterhouses belong to the same horizon, viz. D_3. The shell- and limestone-pebble conglomerate is well seen in the disused quarry north of the station; it contains occasional quartz-pebbles. In this same quarry one of the writers (J. W. J.) has collected a number of interesting corals, including *Michelinia glomerata*, *Favosites parasitica*, and *Alveolites septosa*. The absence of any record of the occurrence of the last-named in the south-western district has been specially remarked upon by Dr. Sibly.[2]

It is not without interest to note that there is strong evidence of earth-movement and erosion in the eastern part of the Midland area in late D_2 times. In a section near Youlgreave, according to Dr. Sibly,[3] black shales of the Pendleside Series clearly overstepped the truncated edges of limestone beds representing a high level in the *Lonsdalia* subzone, D_2. "This section," Dr. Sibly points out, "affords evidence of local earth-movement and erosion, contemporaneous with the deposition, in other parts of the area, of the uppermost beds of the Carboniferous Limestone or the lowest beds of the Pendleside Series." The *Cyathaxonia* Beds, D_3, are absent here, and this may be due either to their removal by denudation during early Pendleside time or to the locality having formed land during *Cyathaxonia* time. Mr. C. B. Wedd[4] has also described a similar example of local unconformity at Darley Dale. It is not improbable that other examples will be found ultimately in the Midland area. The formation of the rolled-shell and limestone-pebble conglomerate (quartzose in part) referred to in this article seems to us to have been the result of the earth-movement and erosion which produced the above-mentioned unconformities.

Conclusions.—The Caldon quartzose conglomerate is a true "Intraformational conglomerate," deposited in D_3 times. It fills an erosion channel in beds of D_2 age at Caldon, these beds, together with the conglomerate, having been subsequently faulted down and

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[1] These beds were assigned to D_3 by Sibly in 1908. See Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 61.

[2] Loc. cit., 1908, p. 48.

[3] Loc. cit., 1908, p. 63 and fig. 5 (p. 62).

[4] Discussion of Dr. Sibly's paper, loc. cit., 1908, p. 81, and Mem. Geol. Surv.: "The Geology of the Northern Part of Derby Coalfield, etc.", London, 1913, p. 35.

thrust along. It is contemporaneous with the other conglomerates overlying D_2 limestones round the north-western and western margins of the Midland Limestone massif. The formation of these conglomerates and the erosion of the Caldon channel appear to have been the result of earth-movement in late, or post, D_2 times, evidence of which is present in the eastern part of the Midland area, near Youlgreave and Darley Dale.

The Metamorphism of the Pre-Cambrian Dolomites of Southern Eyre Peninsula, South Australia.

By C. E. Tilley, B.Sc., A.I.C., Emmanuel College, Cambridge.

(*Concluded from p. 462.*)

(PLATE XI.)

The Calc-magnesian Silicate Rocks of the Hutchison Series.

THE rocks arising from the metamorphism of the more impure dolomitic sediments are calc-magnesian silicate types in which all carbon dioxide has been expelled. In some of the rocks to be described it is clear that superposed on the normal metamorphism there has been a metamorphism by addition of material from the neighbouring magma.

The best exposures of these calc-magnesian silicate rocks are at Sleaford Bay, and they are here closely associated with the dolomites of this area. Fragments of this group have been recognized at Fishery Bay to the south, where they occur as bars in the Flinders gneiss, and they are undoubtedly portions of the Hutchison series engulfed by this intrusion.

The rock-types include Diopside rock, with or without quartz or plagioclase; Diopside–Microcline rocks with scapolite or plagioclase as important accessories. Zoisite, titanite, biotite, and graphite are occasionally important constituents.

(*a*) *Diopside Rock.*

This rock forms a prominent headland on the coast of Sleaford, near Sleaford Mere, and bounding section 14*a*. The interbedded rocks here strike north with a dip of 80 degrees west, to vertical. On the west the diopside rock is bounded by impure diopsidic beds which pass into mica and mica-graphite schists, and on the east it is bounded by garnet gneisses. The whole diopside bed is intimately veined by quartz strings, which traverse it in sill-like fashion. On the transverse joint faces in veins and in vugs there are present well-developed prisms and needles of actinolite.

Under the microscope the rock is seen to consist almost exclusively of a colourless to pale-green pyroxene, with a high extinction angle. It is non-pleochroic, and the individual grains only occasionally show crystallographic boundaries. The rock as seen in hand-specimens is of a pale-green colour, and may vary considerably in texture from place to place. The grain size is, however, usually

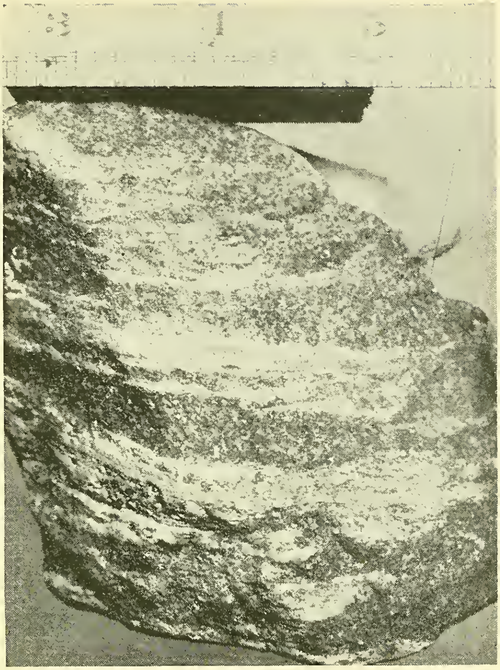

FIG. 1.

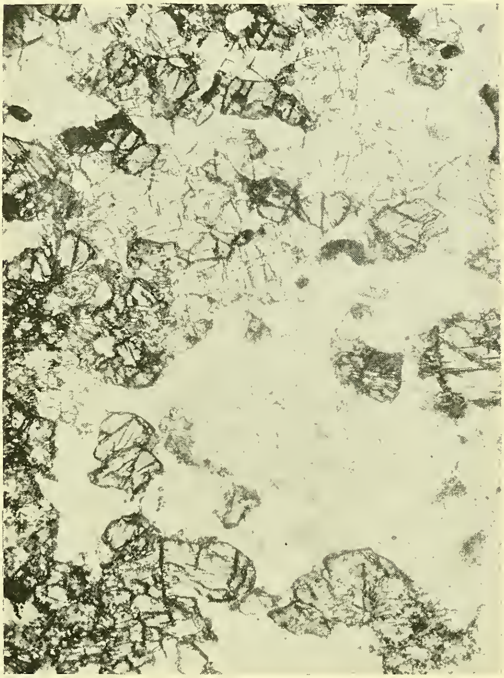

FIG. 2.

medium and of a granular nature. The specific gravity is 3·25. In many cases an incipient alteration to a pleochroic actinolite can be observed in the slides. This may develop peripherally or in isolated spots through the grain. In the associated quartz veinlets flakes of graphite and little rounded grains of diopside are often present. Graphite also occurs along joint faces. The diopside rock occurring as an inclusion in the igneous gneisses of Fishery Bay is essentially similar, but here it has been invaded by the magma in the form of felspar veins.

In these cases the felspar has been very prone to alteration, and in some slides it is represented by its decomposition products as strings through the diopside grains or between and at the corners of these individuals. The original felspar was a plagioclase and had a refractive index greater than C. balsam. In some cases it was as basic as a calcic andesine. Scapolite and zoisite are present in addition to sericite as decomposition products. Hornblende may in some cases be seen as streaks traversing the rock in hand-specimens. Under the microscope an example of this type was seen to consist of diopside and hornblende intergrown without any clear evidence that the amphibole has been derived from it.

A slice cut from a diopside rock developed as a result of the intrusion of a quartz vein in the dolomite of the Waterfall Creek, Hundred of Hutchison, shows greyish diopside, tremolite, and quartz. The rock has been crushed and the tremolite is the result of the crushing of the diopside. The quartz shows undulose extinction, and is in contact with tremolite, this relation being contrary to that expected, if tremolite had arisen as a direct result of silication.

(*b*) *Diopside-Microcline Rocks.*

East of the diopside headland the rocks pass into more aluminous beds, in which diopside is still an important constituent. These rocks have all the appearances of representing a transition into calcareous shales and sandstones from purer dolomitic sediments prior to metamorphism. They are interbedded with rocks that are now garnet gneisses, sometimes carrying sillimanite, and these are probably also metamorphosed sediments.

The diopside-bearing rocks have also suffered intrusion from quartz solutions, as represented by quartz veinlets, and strings traversing them, and these on weathering give the rock quite a serrated appearance. When examined under the microscope these rocks are seen to contain the following silicates, to the exclusion of all carbonate minerals—diopside, microcline, plagioclase, scapolite, biotite, titanite, zoisite, and quartz. Graphite is also usually present in small amount. A typical section is described as under.

No. 160. Diopside is present in light-green coloured grains and often shows crystal outlines. The extinction angles of these diopsides reach a value of 44 degrees, and the light-green colour of the mineral suggests the presence of the hedenbergite molecule entering the constitution. At the periphery and along cracks or cleavages it is changing to actinolite. The potash felspar is present in considerable amount. The type of extinction is that characteristic of certain microclines in which a submicroscopic twinning is suggested.

Scapolite is plentifully distributed in brilliantly polarizing grains, whose double refraction is greater than ·035, and it has the high refractive index corresponding to a scapolite of the meionite end of the series. It is uniaxial and optically negative. The rectangular cleavages are well developed: they are not pinakoidal cleavages, but prismatic, and the extinction of sections which are not quite basal is in accord with this. This apparently is the case for the scapolites of the Grenville series of Ontario as described by Adams and Barlow.[1] The mineral separates with plagioclase from the rock powder in a bromoform-benzol solution of density 2·72. It dissolves in a mixture of strong hydrochloric and hydrofluoric acids without any effervescence.

In thin section the interference colours are as high as third order greens when the diopside gives second order yellows.

Plagioclase is present in small amount, with the usual twinning lamellæ. Separated from the rock powder, it has a specific gravity greater than 2·72. The refractive index is greater than 1·56, but only a few sections show a R.I. greater than 1·57. β is just under 1·57. Most sections give a negative sign, but a few show positive birefringence. The symmetrical extinctions of albite lamellæ reach 40 degrees. The plagioclase is therefore a bytownite, and positive sections indicate a transition to labradorite. The grains are sometimes bordered by a scapolite fringe, and in other cases the grain is broken up and converted into a confused aggregate of scapolite, with isolated sectors of plagioclase.

The remaining constituents are subordinate in amount. Strongly pleochroic actinolite borders the pyroxene, and in a few cases appears to be intergrown with a small amount of biotite. A mineral regarded as sphene is sparsely distributed through the rock. It is usually in more or less rounded grains of a brown colour. Occasionally, however, traces of prism and pyramid faces can be seen, and in such cases the extinction is distinctly oblique. Pleochroism is often noticeable, the change being from a light to a deeper brown.

The axial angle is not large to judge by the curvature of the isogyres. The birefringence is positive, and a strong axial dispersion is to be observed $\rho > v$.

Graphite is present in spongy and irregular flakes, apatite in prisms and grains embedded in microcline, or associated with scapolite. Quartz is quite localized, and is probably part of a veinlet which cuts the rock.

In another rock (216) plagioclase takes the place of scapolite in the type already described. The plagioclase is of the same

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[1] F. D. Adams and A. E. Barlow, Mem. Geol. Surv. Can., No. 6, 1910, p. 102.

composition as in (160), and is undergoing alteration to a sericitic aggregate, potash apparently being derived from neighbouring microcline. Quartz is evenly distributed through the slide. The remaining constituents include zoisite in small amount. This rock formed a portion of a rifted bar of mica schist in a granite sill a few hundred yards to the east of the diopside headland, and is clearly related to the diopside–microcline rocks already described.

Zoisite is plentifully distributed through a rock, otherwise very similar to the type (160) already described. In this rock (123) plagioclase is absent, and its place is taken by clear, colourless grains of meionite. Zoisite is abundant in some parts of the rock, but may disappear in others. This mineral is usually quite irregular in outline, but has a well-developed single cleavage. It is commonly twinned, and the anomalous interference colours are very striking. The plane of the optic axes is at right angles to the cleavage trace, and the extinction is often oblique, angles up to 25 degrees being observed. The sign of the birefringence is positive. These characters agree with the properties of clinozoisite. It is, however, probably not of uniform composition, as judged by the variability of the interference tint seen in one grain. The development of higher interference colours suggests the intergrowth of epidote molecules. Graphite may occur intergrown with the green pyroxene, but it is more characteristically associated with the zoisite, often in irregular bunched aggregates. Quartz is also present.

An interesting rock (106) forms part of the rifted block of mica schist already referred to above. In hand-specimens this rock is characterized by the abundant development of mica, but parallel to the foliation there are developed lenses of green pyroxene and white felspar. The original rock was apparently an aluminous sediment, and contained streaks and lenses of a more calcareous nature. On metamorphism these have developed into diopside-felspar lenses. Examined under the microscope the minerals seen to be present are microcline, diopside, biotite, plagioclase, apatite, and some secondary ragged grains of zoisite.

Diopside is fairly uniformly distributed in colourless grains, with occasional development of uralitic actinolite at the periphery of the grains. Microcline is clear and unaltered, showing the characteristic microcline extinction. Biotite is abundant in flakes, strongly pleochroic in brownish yellow to brown tints, and contains little grains of zircon surrounded by pleochroic haloes.

Water-clear grains of plagioclase felspar are plentifully distributed. The refractive index is considerably greater than C. balsam, and sections showing positive and negative birefringence are present. The extinctions in the symmetrical zone for albite lamellæ, together with the above, indicate a range of composition from labradorite–bytownite to bytownite. Diablastic intergrowths of plagioclase and quartz form bays of myrmekite-like nature into plates of the potash felspar.

THE CHEMISTRY OF THE DEVELOPMENT OF THE CALC-MAGNESIAN SILICATE ROCKS.

We have already referred to the order of development of metamorphic minerals in an impure dolomite. The minerals which first make their appearance are predominantly silicates or aluminates of magnesia, and it is in accordance with this greater chemical activity of MgO that the dominant lime-bearing minerals, as scapolite, plagioclase, etc., are only developed when magnesia has been satisfied.[1] The formation of diopside occurs in the presence of abundant silica, and the occurrence of extensive beds of practically pure diopside is eloquent evidence that the original sediment had the lime-magnesia ratio of a true dolomite. The explanation of the formation of such large masses of diopside rock, however, by metamorphism, without the addition of material, i.e. by residuary crystallization, demands just that amount of silica uniformly distributed through the mass to satisfy the diopside reaction. The conditions yielding such a distribution are, however, not likely to have been attained, and the field evidence strongly favours the view that addition of material in the form of the numerous quartz veins was in part responsible for the diopsidization. The rock as now constituted is to be regarded as a hybrid type, in which silication was partly effected by residuary crystallization and completed by silica solutions from the neighbouring granite, now represented by the numerous quartz veins traversing the diopside rock. Moreover, in the adjoining calc-magnesian silicate rocks, there is abundant evidence of veining of these rocks by quartz strings. For the same reason it is doubtless to the addition of material from the magma, rather than to detrital material present in situ, that we must ascribe the expulsion of the last remnants of carbon dioxide from some of the more aluminous beds.

In the calc-magnesian silicates at Sleaford, and in the Hutchison area, however, there is no reason—with certain exceptions to be referred to below—to invoke the aid of magmatic material other than the purely volatile reagents and silica. The metamorphism, by addition to these rocks, is at most a silication.

In the rifted diopside block in the igneous gneisses of Fishery Bay, the mass is penetrated by felspathic stringers, and this is to be ascribed to the presence of the surrounding fluid magma.

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[1] Cordierite would appear to be an exception to this rule. Its absence in metamorphosed limestones is remarkable. A development in accordance with the equation

$$2\,CaMg(CO_3)_2 + 2\,H_4Al_2Si_2O_9 + SiO_2 = \underset{\text{cordierite}}{(2\,MgO\,.\,2\,Al_2O_3\,.\,5\,SiO_2)} + 2\,CaCO_3 + 2\,CO_2 + 4\,H_2O$$

might be expected, but it would appear that the alumina is absorbed in anorthite, and diopside forms instead.

$$CaMg(CO_3)_2 + CaCO_3 + H_4Al_2Si_2O_9 + 2\,SiO_2 = CaMg(SiO_3)_2 + CaAl_2Si_2O_8 + 2\,H_2O + 3\,CO_2$$

The conversion of diopside in the diopside rock into actinolite in vugs, along transverse veins and joints, is paralleled in the pyroxenites (altered limestones) of Ontario as described by Adams and Barlow.[1] It is stated (p. 91), "a deep green hornblende is also seen occasionally running through the pyroxenite in narrow veins, as if it had developed along cracks."

The impurer dolomitic sediments on metamorphism have ultimately been converted into silicate rocks, in which the minerals diopside and microcline are prime constituents. This association of pyroxene and felspar is one of considerable importance, especially when the nature of the detrital minerals in the original sediment is considered. The development of these minerals can be represented by the following equation, in which sericite and quartz are the detrital materials involved:—

$$(a)\quad CaMg\,(CO_3)_2 + H_2KAl_3\,(SiO_4)_3 + 3\,SiO_2$$
$$= CaMg\,(SiO_3)_2 + KAlSi_3O_8 + Al_2SiO_5 + H_2O + 2\,CO_2$$

$$(b)\quad Al_2SiO_5 + CaCO_3 + SiO_2 = CaAl_2Si_2O_8 + CO_2,$$

and this doubtless represents the case where the diopside and microcline are intimately associated with plagioclase. How far the reaction has proceeded by absorption of excess alumina in the pyroxene is not evident, thus:—

$$(c)\quad 4\,MgCO_3 + 3\,CaCO_3 + H_2KAl_3\,(SiO_4)_3 + 7\,SiO_2$$
$$= \begin{pmatrix} 3\,CaMg\,(SiO_3)_2 \\ MgAl_2SiO_6 \end{pmatrix} + KAlSi_3O_8 + 7\,CO_2 + H_2O,$$

but the very characteristic association of these two minerals, often to the exclusion of other aluminous types in which excess alumina could be absorbed, would seem to demand this equation.

We have already interpreted the formation of phlogopite in the dolomite marbles as a result of an interaction between dolomite and detrital sericite, or sericite and quartz, and it would appear that with an excess of silica this reaction in turn would be further advanced, the resultant phlogopite giving place to diopside and microcline. Using the minerals of the right-hand side of this equation, we have with excess of silica (*vide* p. 459)—

$$(d)\quad H_2KMg_3Al\,(SiO_4)_3 + MgAl_2O_4 + 5\,CaCO_3 + 10\,SiO_2$$
$$= 4\,CaMg\,(SiO_3)_2 + KAlSi_3O_8 + CaAl_2Si_2O_8 + 5\,CO_2 + H_2O.$$

Diopside microcline rocks may thus arise by simple residuary crystallization or the metamorphism may possibly take place in two stages. Firstly residuary crystallization may be only sufficient to produce the phlogopite marble stage, and by a later additive metamorphism[2] the silication of this rock to a diopside microcline type. For the rocks under discussion the view that residuary crystallization is solely responsible for the mineralogical changes

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[1] Loc. cit. supra, p. 91.

[2] Cf. J. E. Spurr, *Econ. Geol.*, vol. vii, 1912, p. 455. This term would be embraced under V. M. Goldschmidt's term "pneumatolytic contact metamorphism".

involved is in accord with both field and microscopic evidence for the majority of types investigated. Where, however, the rocks are intimately penetrated by quartz strings, complete decarbonation cannot necessarily be inferred, prior to the invasion by silica solutions from the granites, and in view of the variability of composition of sediments of this type it is probable that the expulsion of the last traces of carbonate minerals from some of these types was accomplished by siliceous invasions.

Referring to the equation (*c*), it will be seen that the diopside is shown to contain the Tschermak molecule, and the validity of this equation would be considerably strengthened if it were possible to detect the presence of alumina in these diopsides, apart from the fact that excess alumina may enter anorthite in many cases. The optical characters shed little additional light on this question beyond confirming that a pure diopside is not involved[1] (p. 493).

In the case of detrital biotite being a source of some of the MgO of the pyroxene, there may be no available alumina to be dealt with, thus:—

$$K_2Mg_2Al_2(SiO_4)_3 + 2\,CaCO_3 + 7\,SiO_2 = 2\,CaMg(SiO_3)_2 + 2\,KAlSi_3O_8 + 2\,CO_2.$$

But as in most biotites part of the K is replaced by H, this would not be the general case.

The remaining minerals accompanying the diopside–microcline association call for some remark.

Bytownite is characteristic.

With the utilization of all magnesia from the dolomite molecule residual calcite is free to react with alumina and silica, in the form of sericite or kaolin, and anorthite may thus arise, e.g.:

$$CaCO_3 + \underset{\text{kaolin}}{Al_2O_3\,2\,SiO_2,\,2\,H_2O} = \underset{\text{anorthite}}{CaAl_2Si_2O_8} + 2\,H_2O + CO_2.$$

If sericite be the source of alumina, the potash would yield microcline, and the soda of the sericite could be distributed between the microcline and anorthite. (See also the equations already set down.)

With the dwindling of plagioclase in these rocks, a member of the scapolite group takes its place, and although these two minerals may occur together the rocks are usually characterized by an abundance of one or the other. The scapolite of these rocks has been shown to approximate to meionite in composition.

In view of the recent work of Borgström[2] and Sundius[3] on the constitution of Finnish and other scapolites, in which they show

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[1] Diopside microcline rocks have been described by J. S. Flett ("The Geology of the country around Bodmin and St. Austell": Mem. Geol. Surv., 1909, p. 100), and by E. B. Bailey ("The Geology of Ben Nevis and Glen Coe": Mem. Geol. Surv., 1916, pp. 190–4), and the associations in those cases would seem to demand the presence of an aluminous diopside as these investigators have suggested.

[2] L. H. Borgström, Zeitschr. Kryst. Min., vol. liv, 1914, p. 238.

[3] N. Sundius, Bull. Geol. Inst. Univ. Upsala, vol. xvi, 1919, pp. 96–106.

that the dominant meionite molecule is not the oxide type of Tschermak, but of the type $CaCO_3$, 3 $CaAl_2Si_2O_8$, it was of interest to test these scapolites for CO_2.

An uncovered thin section was treated firstly with dilute HCl, and then observed under the microscope. No evolution of gas occurred. More drastic treatment with a mixture of hydrochloric and hydrofluoric acids failed to show evidence of the presence of carbon dioxide. The grains as observed under the microscope slowly dissolved without effervescence.

As far as microscopic tests are available, therefore, there is no evidence to indicate carbon dioxide as an essential constituent of the scapolites of the rocks under discussion. The close similarity in composition between anorthite and meionite, and the conditions under which one or the other is produced in these rocks, are worthy of remark.

It is possible that chlorine of magmatic origin or derived from the sediments themselves may be the determining factor. The suggestion is that, acting catalytically, chlorine may induce the formation of scapolite, which under other conditions would give place to plagioclase. Nor is it, perhaps, essential under these circumstances that scapolite should contain this element in its final constitution.

$$4\,CaCO_3 + 3\,\underset{\text{kaolin}}{(Al_2O_3,\ 2\,SiO_2,\ 2\,H_2O)} \underset{(Cl_2),}{=} \underset{\text{scapolite}}{(4\,CaO,\ 3\,Al_2O_3,\ 6\,SiO_2)} + 6\,H_2O + 4\,CO_2.$$

Titanite, which may be an important constituent, is doubtless derived from the interaction of detrital rutile, calcite, and silica, or the recrystallization of this mineral itself.

CONCLUSION.

Embraced within the oldest group of sedimentary rocks of Southern Eyre Peninsula—the Hutchison series—is a series of dolomites and calc-magnesian silicate rocks. These rocks represent the metamorphosed equivalents of an original sedimentary series, ranging from true dolomites to types in which silica and alumina were abundant detrital constituents.

The series has been invaded and metamorphosed by the succeeding gneisses of the Flinders series. It is shown that for the dolomites residuary crystallization alone can account for the development of the metamorphic minerals.

For the diopside rock masses there is clear evidence that superposed on the normal residuary crystallization is an additive metamorphism—(contact metasomatism of Barrell, or pneumatolytic contact metamorphism of Goldschmidt)—in the form of silica solutions from the granites, and it is to these that the final diopsidization is due. For the diopside–microcline rocks simple residuary crystallization is adequate, but in some examples it is probable that additive metamorphism is responsible for the removal of the last traces of carbon dioxide. The addition of material—

apart from volatile agents—is limited to silica. Where the diopside masses have been engulfed as inclusions in the igneous gneiss, the rock is traversed by felspathic veins derived from the fluid magma.

The writer wishes to record his indebtedness to Dr. Harker, F.R.S., for encouragement and critical discussion during the progress of these studies.

EXPLANATION OF PLATES IX AND XI.

Plate IX.

Fig. 1.—Forsterite Marble, Sleaford Bay. The minerals shown are calcite (turbid), dolomite (limpid). The dark grains are forsterite, showing 010 cleavages. Near the centre is a basal section of edenite. Magn. 28 diameters.

Fig. 2.—Forsterite Marble, Sleaford Bay. Constituents: forsterite, with serpentinous decomposition, calcite, dolomite. Twinning lamellæ in dolomite are seen in relation to the rhombohedral cleavages, in the clear grain below on the left. Magn. 28 diameters.

Plate XI.

Fig. 1.—Diopside Rock, Sleaford Bay. The dark bands are diopside, and the white are quartz veins. The reticulation of the latter is clearly marked.

Fig. 2.—Diopside-Microcline Rock. The clear central area is microcline. In the upper half of the section are basal sections of scapolite showing 110 cleavages at right angles, and diopside. Magn. 28 diameters.

Echinoidea from Western Persia.

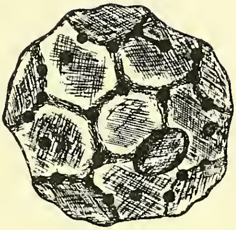
By J. W. Gregory and Ethel Currie, Geological Department, University, Glasgow.

(PLATE XII.)

The Geological Department of Glasgow University has recently received from Dr. W. R. Smellie and Mr. J. V. Harrison some fossils collected by them which throw further light on the age of the limestones of the Persian arc at the north-western end of Luristan, about 100 miles north-east of Baghdad. The locality, Gilan, is on a tributary of the Diala, about 30 miles south-east of Kasr-i-Shirin, a well-known station on the main road from Baghdad to Teheran. The geology of this part of the Persian frontier has been investigated by J. de Morgan (Miss. Sci. Perse, vol. iii, pt. i, Étud. Géol., 1905, pp. 71–112), who has given a geological map (ibid., pl. xix) of an area about 60 miles south-east of Gilan. De Morgan has identified there a folded series of Cretaceous and Eocene limestones, with lacustrine and gypsiferous Miocene beds. The locality at which the fossils were collected by Messrs. Smellie and Harrison is in line with the strike of the rocks in the area of de Morgan's map.

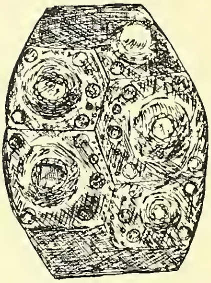
Dr. Smellie's collection was made at Iman-Hasan, near Gilan, from a limestone on the summit of an anticlinal inlier, which is unconformably covered by limestones referred to the Eocene. The fossils include various echinoids, molluscs, brachiopods, corals, and bryozoa. The echinoids give the best evidence of correlation. His collection includes the following echinoids:—

Fig. 1a



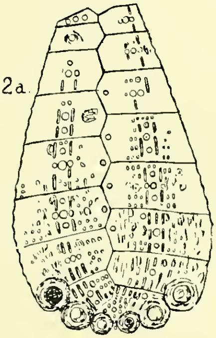
× 4.

Fig. 1b.



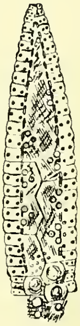
× 4.

Fig. 2a.



× 4

Fig. 2b.



× 4

Fig. 3

× 4

Fig. 2c

× 4

Del. E. Currie.

Cretaceous Echinoidea from Persia.

1. *Rhabdocidaris morgani* Gauthier, 1902 (Miss. Sci. Perse, vol. iii, pt. iii, p. 145, pl. xx, figs. 3–6). Originally obtained by de Morgan from the Upper Senonian in Luristan; the exact locality of the type has been lost. Dr. Smellie's specimen is a well-preserved segment from the Lower Senonian Limestone. He also collected an uppermost interambulacral plate.

2. *Cidaris husseini* Cotteau & Gauthier, 1895 (ibid., vol. iii, pt. ii, p. 82, pl. xiii, figs. 10–12). This species is based on spines which were obtained by de Morgan at Dèrrè-i-Chahr. Dr. Smellie's collection includes six broken spines.

3. *Salenia cossiœa* Cotteau & Gauthier, 1895 (ibid., p. 83, pl. xiii, figs. 13–19). Specimens obtained by de Morgan at Dèrrè-i-Chahr, Endjir-Kuh, and Aftab.

Dr. Smellie's specimen is small and well preserved; diameter 12 mm., height 8 mm. Its characters are illustrated by Pl. XII, Figs. 1*a* and 1*b*.

4. *Codiopsis smellii* n.sp. (Figs. 2*a*–*c*.)

Diagnosis.—Test sub-hemispherical; base slightly contracted. Horizontal section almost circular but slightly pentagonal.

Apical disc.—Periproct pentagonal. Each genital plate has a large pore near the outer edge, and a granule near the edge of the periproct. Each ocular plate bears four large granules and lines of small granules.

Ambulacral areas.—Each pore zone includes 27 pairs of small round pores in a straight vertical series except at the base, where the pairs are in arcs and the pores are smaller and closer. Near the peristome each column has a vertical series of three tubercles which become smaller towards the peristome. The rest of the ambulacral area has very few granules; each ambital plate has three granules arranged in a triangle.

Interambulacral areas.—About three times the width of the ambulacral. About eight plates in each column. At the base of each column three large tubercles occur in a transverse row; of these the adambulacral tubercle is the largest. The plates are ornamented by numerous granules, which are elongated vertically and form two parallel vertical broken ridges. Some of the elongated granules are perforated. Between the vertical ridges is a row of round granules, three in each plate; the middle granule is the largest. Some granules have a distinct mamelon; in others the boss consists of a flat topped ring with a central pit. These pitted granules probably bore the "mamelons radioliformes" of Cotteau (Pal. franç., Terr. Crét., Ech., vol. vii, 1866, p. 774). Dimensions:

	Length.	*Breadth.*	*Height.*
No. 3 . .	1·2 mm.	1·2 mm.	7 mm.
No. 4 . .	1·3 mm.	1·25 mm.	7 mm.

Distribution.—Collected by Dr. W. R. Smellie at Iman-Hasan, Lower Senonian Limestone.

Figures.—Fig. 2*a*, an interambulacrum, × 4 dia. Fig. 2*b*, an ambulacrum, × 4 dia. Fig. 2*c*, apical disc, × 4 dia.

Affinities.—*C. lorini* and *C. doma* differ from this species by the absence of the vertical arrangement of the epistroma. In this respect the new species most resembles *C. arnaudi* Cott. (op. cit., 1866, p. 786) from the Lower Senonian of southern France, in which, however, it is less developed. Amongst recently established species *C. texana* Whitney from the Buda Limestone, Texas, 1916 (Bull. Amer. Pal., vol. v, pp. 91–3, pl. xx, fig. 2), described as nearly related to *C. doma*, differs by having more of its lower pores in arcs and its ornamentation of "fine longitudinal undulating ridges". *C. mortenseni* Lambert (Ann. Univ. Lyon, vol. i, fasc. 30, 1911, p. 176, pl. xvi) is more tubercular, having tubercles on the upper as well as on the lower surface. *C. libanoticus* de Lor., 1901 (Notes pour servir Ét. Ech., 1901, p. 27; cf. R. Fourteau, 1913, Bull. Inst. Egypt, vol. vii, p. 57, pl. vi, fig. 6) closely resembles *C. lorini* Cott. var. *alpina*; but Fourteau's figure shows no sign of the vertical epistroma of *C. smellii*.

5. *Pyrina orientalis* Cotteau & Gauthier, 1895 (op. cit., p. 68, pl. xi, figs. 1–8). De Morgan obtained his specimens from Dèrrè-i-Chahr and Endjir-Kuh.

Dr. Smellie's specimen from Gilan has the dimensions—length 24 mm., breadth 20 mm., height 15 mm.

6. *Echinoconus douvillii* Cotteau & Gauthier, 1895 (ibid., p. 70, pl. xi, figs. 9–13). De Morgan's specimens are from Dèrrè-i-Chahr and Aftab.

Dr. Smellie collected two specimens (Nos. 5 and 6):—

	Length.	*Breadth.*	*Height.*
No. 5 . . .	27 mm.	24 mm.	19 mm.
No. 6 . . .	25 mm.	22 mm.	16 mm.

No. 5 shows well the arrangement of the pores near the peristome in oblique triplets (Fig. 3).

7. *Hemiaster parthicus* Gauthier, 1902 (ibid., p. 137, pl. xx, figs. 1 and 2). De Morgan's specimen was obtained in Luristan; the exact locality is unknown.

In Dr. Smellie's specimen (No. 6*d*) the dorsal keel is broken, and the apical disc is hidden by the interambulacral areas which have been pressed over it.

Dimensions.—Length 28 mm., breadth 27 mm., height 18 mm.

Dr. Smellie has sent with the echinoids a few molluscs which include some young oysters, the *Lopha morgani* Douvillé. The brachiopoda include *Terebratula brossardi* Th. & Pér.

The age of this fauna is unquestionably Senonian, and apparently Campanian. It corresponds with the fauna of the "echinoid limestone" of de Morgan, who placed it in the Mastrichtian, but at the base of that division. The evidence of the echinoids is in favour of the horizon being pre-Mastrichtian, but still Senonian.

The second fauna was collected by Mr. J. V. Harrison in the same district, at the locality of Tang Diarah, near Gilan. The fossils include some echinoids, most of which have been rather distorted.

The collection includes the following species:—

1. *Schizaster vicinalis* Agassiz & Desor, 1847; Gauthier, 1902 (op. cit., p. 172, pl. xxiii, fig. 4). Obtained by de Morgan from the Upper Eocene at Mollah Ghiavan. Mr. Harrison's specimen is from the Upper Eocene at Tang Diarah. It is somewhat distorted.

Dimensions.—Length 48 mm., breadth 44 mm., height 25 mm.

2. *Schizaster rimosus* Desor, 1847; Gauthier, 1902 (ibid., p. 174, pl. xxiii, fig. 5). De Morgan's specimens are from the Upper Eocene at Mollah Ghiavan.

Mr. Harrison's specimen from Tang Diarah is poorly preserved. This species resembles *S. vicinalis* in many ways. It is distinguished therefrom by its unpaired and paired anterior ambulacral grooves being narrower, and by the posterior petals being relatively a little longer.

3. *Ditremaster nux* (Desor), 1853; Gauthier, 1902 (op. cit., p. 164, pl. xxi, figs. 9–11). De Morgan collected many specimens from the Upper Eocene at Mollah Ghiavan. Mr. Harrison's specimens from Tang Diarah have the following dimensions:—

	Length.	*Breadth.*	*Height.*
H_3 . . .	24 mm.	22 mm.	19 mm.
H_4 . . .	27 mm.	23 mm.	21 mm.
H_7 . . .	15 mm.	13 mm.	11 mm.

These dimensions do not agree with those of de Morgan's specimens which are as broad as they are long; but Mr. Harrison's specimens are somewhat crushed. They may belong to the oval variety of *D. nux* mentioned in Pal. franç., Terr. tert., vol. i, p. 422.

4. *Euspatangus ghiavanensis* Gauthier, 1902 (op. cit., p. 156, pl. xxi, figs. 1 and 2). This species was originally obtained by de Morgan from the Upper Eocene at Mollah Ghiavan. Mr. Harrison's specimens are from Tang Diarah. Dimensions:—

	Length.	*Breadth.*	*Height.*
H_{12} . . .	30 mm.	26 mm.	13 mm.
H_{13} . . .	22 mm.	20 mm.	10 mm.
H_8 . . .	24 mm.	21 mm.	10 mm.

The age of this fauna is unquestionably Upper Eocene. Some Middle Eocene echinoids are known from the Pusht-i-Kuh area, but none of those Middle Eocene species is present in Mr. Harrison's collection.

The Iron Ore Supplies of the World.

By F. H. Hatch, M.Inst.C.E., Past-President Inst. Min. Met.

The following article originally appeared in the special "Iron and Steel" number of the *Times* Trade Supplement on July 21 last. It is here reprinted, with some small additions, by the courtesy of the proprietors of that journal.

WITHIN the limits of a brief article such as this must necessarily be, it is impossible to do more than indicate the chief sources of iron-ore supply. The subject is a big one, and of great importance, not only to the British ironmaster, but also to every inhabitant of this country. I am therefore pleased to be able to state that the Federation of Iron and Steel Manufacturers has not only asked the Imperial Mineral Resources Bureau to prepare a summary of the existing information as to the iron-ore supplies of the world, but is also assisting to finance the inquiry. This will mean a more complete survey than is possible to-day.

Any attempt to estimate the world's iron-ore resources is complicated both by the diversity of the products manufactured from the raw material and by the numerous factors which go to connote a commercial iron-ore. Among these the iron content, the presence of beneficial or deleterious constituents, physical condition, geographical position, and means of transportation are all considerations of the first importance.

First consider the iron-content. According to the estimate of the American geologist, Clarke, the crust of the earth contains 4·4 per cent of metallic iron, of which but a very minute fraction has been sufficiently concentrated by geological agencies to form commercially available iron-ores: for one ton of these that contains 60 per cent of iron there are very many tons that contain 50 per cent; while for one ton that contains 40 per cent there are vastly more that contain 30 per cent, and so on. The amount of reserves in an iron-ore field can, therefore, be indefinitely increased by lowering the grade of the material to be included.

With regard to the presence of beneficial or of deleterious constituents, what is prejudicial in one case is beneficial in another. The requirements of the smelters are decisive on this head. If hæmatite pig iron for the acid process of steel-making is required, phosphorus is barred; if, on the other hand, the iron is destined for the basic process, phosphorus is a desideratum. Titanium rules out vast bodies of ore containing a high percentage of iron, because the presence of titanic acid in any notable proportion raises the temperature of fusion and leads to greater fuel consumption and a heavier blast. A small quantity of manganese, on the other hand, is beneficial, since it helps to get rid of sulphur. A high silica-content is an objection, because of the limestone that has to be added to the charge to neutralize the acid constituent, thereby reducing the output per furnace and increasing the cost per ton of pig; but a calcareous ore is sought after, since it is either self-fluxing or can, if the lime is present in excess, be mixed with siliceous ores in the proportion required for a fusible charge. A self-fluxing ore containing 25 per cent of iron may be as valuable as, or even more valuable than, a refractory ore containing 35 or 40 per cent. Therein lies the virtue of the calcareous ores of Frodingham in North Lincolnshire.

The physical condition of the ore is of the highest importance. If the ore is friable, disintegrates during transportation, and arrives at the smelting works in a dusty condition, or "decrepitates" when heated, it chokes the furnace, prevents the free passage of the gases, and leads to dust losses. Although friable ores can be improved by sintering or nodulizing, this can only be done at the expense of a heavy increase in the cost of production. On the other hand, a hard, dense ore, such as certain classes of magnetite, is refractory, and consequently not looked upon with favour by the ironmaster, except for enriching purposes.

The position of an iron-ore field in regard to the smelting centre has the greatest influence of the utility of the ore. An ore may be desirable in all other respects, but inaccessibility may prevent its use. A notorious case is Brazil, where vast deposits of the best class of iron-ores remain unworked because of their unfavourable geographical position.

The first attempt at a census of the iron-ore resources of the world was an inquiry made upon the initiative of the Executive Committee of the International Geological Congress, which met in Stockholm in 1910, and based on the returns obtained from official and non-official geologists all over the world. A summary of the returns from the five continents made by H. Sjögren showed that the actual known reserves of the world amounted to 22,400 million tons, of which the equivalent iron was estimated to be just over 10,000 million tons, or, at the then rate of pig-iron production of 60 million tons per annum, insufficient to last for 200 years, without allowing for any increase in consumption. Since 1910 the extension of knowledge by exploratory and development work has led to repeated revisions of Sjögren's figures.

The principal known iron-ore reserves of the world are those of the Eastern United States, Newfoundland, Cuba, Brazil, Lapland, Spain and the north coast of Africa, the Central European orefield, and the United Kingdom. There are probably also considerable reserves in India, South Africa, Australia, and Canada.

UNITED KINGDOM.

Of the 15 million tons of iron-ore produced in 1918 in the United Kingdom, 80 per cent consisted of Jurassic ironstones, 10 per cent of West Coast low-phosphorus hæmatite, 8 per cent, of Coal Measure ironstone, and 2 per cent came from miscellaneous sources.

An estimate of reserves was made by the Geological Survey in 1917. Taking the Jurassic ironstones first, the following are the tonnages arrived at for "reserves partially developed", under the headings of ore to be got (1) by open-cast work and (2) by underground mining, from which I have made a deduction for the ore won during the years 1917–19.

	Open-cast, million tons.	Mining, million tons.	Total, million tons.
CLEVELAND MAIN SEAM . . . North Yorkshire.		177	177
MARLSTONE . . . . Lincolnshire, Leicestershire, Oxfordshire, and Warwickshire.	94		94
FRODINGHAM BED . . . . . North Lincolnshire.	154	336	490
NORTHAMPTON BED . . . . . Northamptonshire, Huntingdonshire, Rutlandshire, and Lincolnshire.	1,344	539	1,883
Total . . .	1,592	1,052	2,644

In addition, 26 million tons are assigned to the Westbury (Corallian) ironstone, and 10 million to the Raasay ironstone, neither of which are at present being worked as a source of iron. This brings the total for the Jurassic ironstones to 2,680 million. It is not claimed that these figures are estimates of actually merchantable ore. It is possible that much of the low-grade ore that it is now found profitable to work in open quarries will not constitute an economic proposition when mining has to be resorted to.

The reserves of clay-ironstones and blackband ironstones in the Carboniferous strata of England and Wales are estimated by the Survey at 1,057 million tons. The Scotch Coalfields are estimated to have a reserve of 93 million tons of ironstone, making 1,150 million tons in all. Much is included that in all probability will never be mined. The richer and thicker seams of blackband have long since been worked out, and the present output comes mainly from North Staffordshire and Scotland. In 1918 out of a total output of 1,120,000 tons of Coal Measure ironstone, 1,052,000 tons came from those districts. The clay-ironstones, too, are not worked systematically except in a few places; in many collieries the clayband ribs are only taken down in "brushing" the roads, and in the case of a ball-ironstone the balls are put aside as they occur during the working of the coal, or fireclay, as the case may be, and marketed when a sufficient quantity has accumulated. The output of Coal Measure ironstone, which amounted to over 6 million tons per annum in the 'seventies, has been falling for many years, and is now little over a million tons per annum. The Director of the Survey, in an introduction to the Memoir on the Carboniferous Bedded Ores, states his belief that under present conditions only about half the amount estimated would be available, and in the Memoir dealing with the iron-ores of Scotland a 30 per cent deduction for losses in mining is suggested. For the present purpose a round 50 per cent of the total given for areas partially developed is taken, which brings the total reserves for Coal Measure ironstone down to 575 million tons of ore of about 30 per cent grade.

In all, therefore, the low-grade ores of the United Kingdom are estimated at 3,219 million, or, say, in round figures 3,000 million tons of 30 per cent ore.

The reserves of low-phosphorus hæmatite of Cumberland and Lancashire are estimated by the Survey at 40 million tons. The grade may be taken at 50 per cent.

SPAIN AND NORTH AFRICA.

Spain has in the past been the principal source of supply for the high-grade low-phosphorus ores used in European furnaces. The production reached 10 million tons in 1913; but it fell to about half that amount during the War. For many years British makers of hæmatite pig for Bessemer and Siemens Martin steelworks have derived the greater proportion of their ores from Bilbao (some 2½ million tons per annum); but three-quarters of the workable ore has already been mined, and for some time there has been a gradual deterioration in quality due to the exhaustion of the richer mines.

The low-phosphorus ores of Bilbao consist of *vena*, *campanil*, *rubio* (all three varieties of hæmatite), and *spathic* (the carbonate); but the qualities now exported are practically confined to "rubio" and calcined "spathic". The standard guarantee for "best rubio" is 50 per cent iron, 8 per cent silica, and under ·02 phosphorus, but many shipments run about 47 per cent iron, 10 per cent silica, and ·025 phosphorus. The guarantee for "best calcined spathic" is 56 per cent iron, but on account of fuel scarcity cargoes of about 54½ per cent iron and 9½ per cent silica are delivered. Among other ores imported are the Santander washed granular ores, but these, being higher in phosphorus, can only be used in combination with a considerable proportion of other purer ores. Rubio ore is also worked at Castro (Dicido) in Santander, and considerable reserves of low-phosphorus and low-silica ore with iron 47 per cent exist in Almeria (Alquife). A large quantity of ore is mined in Seville and Teruel (Sagunto). Deposits of hæmatite, magnetite, brown ore, and carbonate are also known in the following provinces: Guipuzcoa, Oviedo, Leon, Lugo, Malaga, and Granada; but they have not been much developed and the extent to which they will be worked in the future depends on the results of investigation and the provision of adequate transport facilities. Few of the ores are equal in quality to those of Bilbao.

The Stockholm estimate for the actual reserves of Spain, brought up to date by the Imperial Mining Resources Bureau, is 650 million tons, of which 28 million is credited to Bilbao.

High-grade ores (averaging about 50 per cent iron) are found on the north coast of Africa in various parts of the Atlas Mountains in Algeria, Tunis, and Morocco; in large part they are of Bessemer grade. The production of these fields amounted in 1913 to close on 2 million tons, of which three-quarters of a million went to England. The principal producers are Benisaf, Zaccar, and Timezrit in Algeria, Djerissa in Tunis, and Riff in Morocco. It is estimated that the output can be increased by half a million tons or more a year by completing the railway from the port of Bona to the Ouenza and Bou Kadra mines, which are in Algeria near the Tunisian border, and about 120 kilometres from the coast. The reserves for North Africa have been estimated at from 100 to 150 million tons.

SCANDINAVIA.

Swedish iron has long been celebrated for its purity and general excellence. The low-phosphorus ore used in its manufacture is in the main magnetite, and comes from a number of old mines in southern Sweden, among which may be mentioned the celebrated Dannemora and Persberg mines. It is smelted locally with charcoal and the reserves are comparatively small. In central Sweden there are some large hæmatite deposits, as, for example, those of Grängesberg and Norberg, which yield ore averaging 60 per cent iron and high in phosphorus. The reserves are estimated at about 100 million tons.

The main resources of Sweden are in Lappland. Great deposits of iron-ore occur there, mainly magnetite and, as a rule, high in phosphorus, although a trifling proportion is of acid Bessemer grade. The largest and most celebrated ore bodies are those of Kiirunavaara and Gellivare, the former (together with Luossavaara) being credited with a reserve of 738 million tons, and the latter (including Kokullskulle) with 265 million. Both ore-bodies were formerly worked on the open-cast system, but underground mining has recently been substituted at Gellivare. They are owned by the Trafikaktiebolag Grängesberg-Oxelösund of Stockholm, and the ores are sold by this Company on a basis of 60 per cent iron, as received, the following grades being distinguished by the phosphorus content:—

Grade.	Phosphorus, per cent.
C^1	Not more than 0·6.
C^2	Not more than 1·0.
D	Over 1·0 and not more than 2·0.
G	Over 2·0.

The output is limited by law to 1,300,000 tons per annum for Gellivare, and 5 million per annum for Kiruna.

The shipping ports are Narvik, on the Atlantic coast, and Luleå, on the Baltic. The former is open all the year round. Before the War

80 per cent of the output went to Germany, but in 1916 a contract was made with the Swedish Government which secured for the United Kingdom approximately 50 per cent of the output.

In Norway the deposits, although large, are of low grade, and require concentration. The present production is small. The most important is that at Sydvaranger, on the northern coast, the shipping port, Kirkenes, on the south side of Varanger Fjord, being within the Arctic Circle. The ore is a low-phosphorus magnetite, occurring in close association with apatite and interbedded with quartz. The bulk of it averages from 30 to 35 per cent iron, and is worked open-cast; but a smaller quantity of 50 per cent ore is mined. To free the ore from apatite a magnetic concentration plant is used, yielding a product which, when briquetted, contains 65 per cent iron and ·02 phosphorus. The reserves are estimated at 100 million tons raw ore. At Dunderland, on the west coast, there is a large deposit of mixed hæmatite and magnetite in association with apatite, the raw ore averaging about 35 per cent iron with a high phosphorus content. By special methods of concentration it is stated that the magnetite and hæmatite can be separated, and the grade of the ore brought up to 68 per cent iron, with only ·03 per cent phosphorus. The reserves are estimated at 150 million tons.

The estimate of the Scandinavian reserves as a whole made by the Swedish geologists for the Stockholm Report, but as revised and brought up to date by the Imperial Mineral Resources Bureau, is as follows:—

	Million tons.	Average iron content. per cent.
Northern Sweden .	1,003	60
Central and Southern Sweden . . .	116	57
Norway . . .	350	35
Total . .	1,469	

Say, 1,500 million tons of 54 per cent grade.

CENTRAL EUROPE.

The "minette" orefield, which extends over a portion of Alsace-Lorraine, Luxemburg, and Belgium, is the most important, in regard to quantity, in Europe, and the struggle for its possession was one of the main causes of the late War. The annexation in 1871 of the eastern part of the field gave Germany the means of building up a great iron trade, while the early occupation of the Briey and Longwy basins proved a severe handicap to France during the progress of the War. This field in 1912 produced 44 million tons or 28 per cent of the world's output, divided between Germany, Luxemburg, and

France. The ore—geologically a bedded oolitic ironstone of Jurassic age—is a carbonate, partly oxidized to brown ore, containing from 27 to 36 per cent iron, as mined, with an average of 10 per cent moisture. The ores are in part siliceous, in part calcareous, and good smelting charges can be obtained by mixing these two varieties in suitable proportions. A valuable feature is the high-phosphorus content, permitting the manufacture of a basic pig containing from 1·7 to 1·9 per cent phosphorus, and suitable for the basic Bessemer or Thomas process. In the greater portion of the field only one bed (the "grey bed") is worked; but its thickness varies from 6 to 20 feet and the reserves are very large, being generally put down at about 5,000 million tons.

Besides the minette ores, France possesses in Normandy, Anjou, and Brittany, oolitic bedded ores of Ordovician age. These occur in a number of detached synclines either as carbonate or hæmatite. The ores (calcined in the case of the carbonate) average from 45 to 48 per cent iron, 10 to 20 per cent silica, and 0·4 to 0·8 per cent phosphorus. They are smelted to basic iron at the Mondeville works, near Caen, for the Normandy deposits, and at the Trignac works, near St. Nazaire, for the Brittany and Anjou deposits. The reserves are estimated to be about 200 million tons.

With the cession of Alsace-Lorraine, Germany lost its biggest orefield, but it retains a number of smaller producing districts, the reserves of which amount to some 1,300 million tons.

UNITED STATES.

Lake Superior produces four-fifths of the iron-ore output of the United States. (In 1918 it was 86 per cent of a total of 70 million tons.) The ore is derived from a series of ranges in Minnesota, Wisconsin, and Michigan, respectively known as the Mesabi, the Marquette, the Menominee, the Gogebic, the Vermilion, and the Cuyuna, the order given being that of the importance of the annual production. At first all the ore was obtained from open-workings by steam-shovel and other forms of mechanical excavator, and was shipped without further treatment. Mining is, however, becoming more and more necessary, and in places water-concentration, and even calcining, are being introduced in order to raise the iron content and diminish the silica and sulphur. The ore is in the main a hæmatite, but in part is hydrated. Magnetite is only found in the Marquette range and in small proportion. The average iron content of the ore mined is diminishing, having fallen from 56·2 per cent in 1902 to 52 per cent in 1912. The phosphorus content, too, is increasing, the percentage of Bessemer ore having fallen from 64·9 in 1902 to 42·9 in 1912.

From the iron ranges the ore is railed to the shipping ports of Duluth, Ashland, Marquette, and other ports at the western end of Lake Superior, and from there shipped by water to be smelted in Chicago, on the shore of Lake Michigan, or at Cleveland and Buffalo on Lake Erie. The bulk of it, however, is passed on by rail to Pittsburg and other industrial centres of Pennsylvania and Ohio, the total distance by water and rail to Pittsburg being about 1,200 miles, and thus greater than that of the iron mines of Spain and Scandinavia from British or German furnaces. Cheap water transportation on the Great Lakes has made this possible. The ore-ships are loaded direct from the ore-trains at the rate of 10,000 tons in half an hour, and discharged at the receiving dock in less than half a day. In 1913 the rate for water transport and unloading averaged less than ·07 of a cent, or (at normal exchange) ·035 of a penny per ton-mile. Although navigation is closed for about five months in the year, and a stock pile of 25 million tons has to be accumulated at the loading end, over 60 million tons a year are conveyed in this manner, and by the end of 1918 the Lake District had marketed no less than 900 million tons of ore.

A recent estimate of the available reserves at Lake Superior is 2,750 million tons of an average grade of 52 per cent iron (*Mineral Industry*, 1918).

The red or Clinton hæmatites are bedded oolitic ores of Silurian age cropping out on the eastern flank of the coalfield from Maryland through Virginia and Tennessee to Georgia and Alabama. They reach their highest economic development in the Birmingham district of Alabama, although they are also worked in Georgia and Tennessee, and to a small extent in Virginia. Although the Clinton ores as a whole are rather high in silica, this is to a considerable extent offset by the presence of a good proportion of lime carbonate. Including the Brown Ores worked in the Appalachian Valley and in Tennessee, these south-eastern states had, up to 1918, produced 10 per cent of the whole iron-ore output of the United States. The available reserves are estimated at 1,750 million tons of 36 per cent grade phosphoric ore.

The north-eastern states (New York and New Jersey and Pennsylvania), contribute 1 per cent of the total iron-ore output of the United States. The ores are derived from magnetite mines in the Adirondack region of New York, from Clinton ores in Pennsylvania, and from Brown Ore in Northern New Jersey. In the main they are phosphoric ore, and are used locally. The undeveloped reserves, with an average grade of 35 per cent iron, are estimated at 2,500 million tons.

The following table gives in parallel columns the most recent estimates and those made for the Stockholm Geological Congress :—

Stockholm.	Million tons.	Recent Estimates. (*Mineral Industry*, 1918.)	Million tons.
Lake Superior	3,500	Lake Superior	2,750
Clinton Ores	505·3	S.E. States (Clinton, etc.)	1,750
Miscellaneous	252·5	N.E. States	2,500
	4,257·8		7,000

It will be seen that in comparison with recent estimates, the Stockholm report over-estimated the Lake Superior area, but did not attribute sufficient importance to the remaining areas. Neither estimate includes any of the very low-grade red or Clinton ores, or of the low-grade siliceous ores of the Lake District, of both of which there are enormous quantities.

BRAZIL.

One of the greatest ore reserves of the world, and certainly the greatest reserve of ore suitable for the acid Bessemer process, is situated in the province of Minas Geraes, in Brazil.

The ores are hæmatite and magnetite, and occur in rocks similar to the banded jasper of North America and South Africa. They vary in grade, but the average iron content is over 60 per cent, and the phosphorus is in the main well below the Bessemer limit. A proportion of the ore occurs in thin lamellæ between siliceous layers, but there are large masses of practically pure oxide, like that of Iron Ore Peak (Itabira do Campo) and the Caué deposit of Itabira do Matto Dentro, which is estimated to contain 80 million tons of the highest quality ore. E. C. Harder states that the largest deposit contains at least 350 million tons, and that there are numerous ore-bodies of from 10 to 50 million tons. Their possible aggregate tonnage is enormous, but with the present means of transportation the greater portion is inaccessible. Before the War capital was being found to develop these fields and to provide transportation, and it cannot be long before such valuable deposits will be utilized in the world's markets. The ore will probably be exported in great quantity to British and American Bessemer furnaces.

The economically important ores of Minas Geraes are usually divided into (*a*) *Bedded or Quarry Ores*, consisting of (1) thick bedded massive hematite, and (2) thinly bedded siliceous hematite ("jacutinga"); (*b*) *Fragmental Ores*, consisting of (1) rubble ore (a denudation product of the bedded ores), and (2) Canga (recemented rubble).

The massive ore beds vary in thickness from less than a foot to more than 300 feet, but they are less extensive than the jacutinga ores. Leith and Harder state that single lenses of jacutinga are known more than 3 miles in length and up to 2,000 feet in thickness. Of the high grade massive hæmatite and jacutinga, ranging in iron content from 63 to 69 per cent, the tonnage was stated by Leith, in 1911, to be probably not far short of the total reserves of the Lake Superior district available at that date. The Canga and rubble ores are of lower grade; even these probably average 50 per cent in iron, but the phosphorus is higher than in the bedded ores.

Estimates of the total available reserves in the Minas Geraes field vary from the conservative estimate of 2,000 million tons made by Dr. Derby for the Stockholm Report, up to recent estimates of 3,500 millions. For the whole iron ore region of Brazil, Merriam and Leith estimate the potential reserves at 7,500 million tons of ore; while *Mineral Industry* (1918) credits Brazil with 5,000 million tons of 63 per cent grade. With regard to the phosphorus content it must be borne in mind that while the quantity of Bessemer ore is very great, in all probability exploration will show that a proportion of the ore is above the Bessemer limit.

CUBA.

The Stockholm estimate for Cuba was 1,903 million tons. More recent estimates agree in placing the reserves at from 2,500 to 3,000 million tons of crude ore (36 per cent iron) for the lateritic blanket deposits of the north coast. There are three distinct ore-fields, namely, those of the districts of Mayari, Moa, and Levisa, of which Mayari is the only one worked at present. The soft, clayey ore is removed by mechanical excavators to an average depth of 19 feet, and there is no overburden. Since it contains from 20 to 30 per cent of moisture, and about 13 per cent of combined water, it is calcined in nodulizing kilns before being shipped to Sparrows Point and Steelton, in the United States, losing thereby one-third of its weight. According to Weld, the nodulized ore averages 55 per cent iron, 4·50 per cent silica, 13 per cent alumina, 1 per cent nickel, and 2 per cent chromium; phosphorus is below the Bessemer limit, and sulphur is negligible. Mixed with other iron, the pig produced from these ores is used for making chilled castings; but the bulk of it goes to make steel for rails, truck-bolts, and all sorts of motor-car parts. The steel is stated to contain from 1 to 1·5 per cent of nickel, and from 0·2 to 0·7 per cent of chromium, with sulphur and phosphorus below 0·04 per cent.

NEWFOUNDLAND.

No exact estimate of the iron resources of Newfoundland is possible, since, with the exception of a small area where the ore beds outcrop on Bell Island, the whole of this field is under Conception Bay. The ore is a dense bedded hæmatite, averaging over 50 per cent iron, 0·8 per cent phosphorus, and about 10 per cent silica, and therefore suited for the basic process. It occurs in three workable beds of an aggregate thickness of 30 feet, in a trough of Ordovician rocks, which, dipping at a low angle from the outcrop on Bell Island, passes under the sea.

The Wabana mines on Bell Island are operated by the Nova Scotia Iron and Coal Co. and the Dominion Iron and Steel Co., the former company working the upper beds and the latter company the lower bed. The combined output averages about 700,000 tons per annum. The Nova Scotia Co. has recently completed two inclined shafts, by means of which 12,000 tons a day is being raised from workings 2 miles to the dip under the sea. The whole enterprise has recently been merged in the Empire Steel Corporation, in which both British and Canadian capital participate.

The amount of ore ultimately to be recoverable will depend on the engineering skill that can be brought to bear on the problems of ventilation and pumping that such extensive submarine mining will present. E. C. Eckel estimates the economically workable ore at 3,500 million tons of 50 per cent ore within a radius of 5 miles of Bell Island. Newfoundland was credited with 3,635 million tons in the Stockholm Report.

CANADA.

Very little is known regarding the iron resources of the Dominion. Of the 1¾ million tons of iron-ore smelted in Canadian blast-furnaces in 1919, only 5 per cent was of domestic origin, the balance coming from Lake Superior mines in the United States and from the Wabana mines of Newfoundland. The domestic ores are sedimentary hæmatite ores from Nova Scotia, magnetite from New Brunswick, Eastern Ontario, Quebec, and Texada Island, in British Columbia, and spathic ore from the Michipicoten district of Ontario. The carbonate ore at the Magpie mine, worked by the Algoma Steel Corporation in the latter district, averages 34 per cent iron for the raw stone, and 50 per cent for the calcined material. The low-grade magnetite deposits worked by the Moose Mountain Company at Sellwood, in Ontario, average 34 per cent iron, but the briquetted concentrates run as high as 63 per cent.

The total reserves of the Dominion have been estimated at only 150 million tons, but with the vast unexplored country in Northern Canada it is hard to believe that big reserves will not some day be discovered.

SOUTH AND WEST AFRICA.

Iron-ore of various types are known to exist in South and West Africa. Lateritic deposits similar to those of Cuba, and characterized by a rather high silica and alumina content and small percentages of nickel, chromium, manganese, etc., are common in many parts of the country. One in French West Africa has recently been found to have a reserve of 100 million tons, and to yield a nodulized product running over 60 per cent iron. Hæmatite-magnetite deposits associated with Pre-Cambrian rocks occur over large areas; but they are generally too interlaminated with siliceous material to be workable. This type, however, is stated to be of economic importance in Rhodesia. In the Transvaal there are extensive deposits of low-grade phosphoric ores in the Pretoria Beds, near Pretoria, and at Boskop, near Potchefstroom, which can be used as mixing ores; but the most valuable deposit yet discovered is a high-grade low-phosphorus hæmatite with over 60 per cent iron, occurring at Kromdraai, 45 miles north-east of Pretoria, which it is proposed to mix with the lower-grade phosphoric ores of Boskop for the manufacture of basic pig at Vereeniging.

With the existing data no estimate as to reserves can be made, but it appears certain that large tonnages of iron-ore are available in the Transvaal, from which suitable mixtures for smelting to basic pig can be made.

INDIA.

The following particulars with regard to India are taken from a note kindly prepared for me by Dr. Coggin Brown, of the Indian Geological Survey.

Important deposits of high-grade iron-ore, mainly hæmatite, associated with banded jasper, and in this respect similar to those of Lake Superior and Brazil, have recently been opened up in India. The best-known deposits are those of Mayurbhanj and Singhbhum, in Bihar and Orissa; Chanda and Drug in the Central Provinces; Kadur in Mysore; and Goa. The Mayurbhanj deposits are being worked by the Tata Iron and Steel Company at Gurumaishini, where a lens of hæmatite has been proved to contain 15 million tons for every 10 feet of depth. This ore averages over 60 per cent iron, manganese 0·8, sulphur 0·01, and phosphorus 0·09. The basic pig made from this ore at the Tata Ironworks, which are situated within 40 miles of the mine workings, contains about 0·04 per cent phosphorus, under 0·05 sulphur, and less than 1 per cent silicon. Similar ore bodies are known at Okampad and Badampahar.

The Singhbhum deposit is being worked at Pansira Hill and Budu Hill, south-east of Manharpur, on the Bengal-Nagpur Railway. It appears to be a part of an iron-ore range forming a definite horizon in the Dharwar rocks, and extending for some 40 miles in a south-westerly direction from Singhbhum. Enormous quantities of ore are believed to exist, but until the supposed extensions have been definitely proved in depth by drilling, no estimate as to quantity can be made.

In the Chanda and Drug districts of the Central Provinces, deposits of high-grade low-phosphorus ore have been discovered, but have as yet not been extensively prospected. The Mysore ores are not of great extent. They are being worked tentatively by the Tata Iron and Steel Company, for the Mysore Government. High-grade low-phosphorus ores exist in Goa and Ratnagiri, probably in considerable quantity; but they have not as yet been proved in depth.

Altogether the reserves of high-grade ore already partly proved in India may be safely put at several hundred million tons, and the prospects are favourable for the existence of very much larger quantities.

AUSTRALIA.

Little is known of the iron-ore resources of Australia except that many important deposits exist both near the coast and in the interior. Some of these are at present being investigated in South Australia, Western Australia, Queensland, and Victoria.

A high-grade ore is being worked in South Australia by the Broken Hill Proprietary Company at Iron Knob. The ore is carried at low cost by water transportation to the Company's ironworks at Port Waratah near Newcastle in New South Wales, where it is smelted to basic pig for open-hearth steel manufacture. Work at Iron Knob is at present restricted to quarrying, and the output is about 300,000 tons per annum. No figures as to reserves are available.

CONCLUSIONS.

Summarizing the estimates for the great ore-fields of Europe and the Americas (namely, the United States, Cuba, Newfoundland, Brazil, Scandinavia, Central Europe, the United Kingdom, Spain, and North Africa) we arrive at the following round figures :—

	Million tons.
High-grade low-phosphorus ore . .	6,740
High-grade phosphoric ores . .	6,460
Low-grade ores	17,100
Total	30,300

Another 1,500 million should be added for the small ore-fields of Russia, Austria, and Greece in Europe, and Chile, Venezuela, Mexico, and Canada in America, making a grand total for the two continents of 31,800 million tons, of which the equivalent iron is 14,310 million tons, or, on the basis of a pig-iron production of 70 million tons a year, sufficient to last over 200 years.

The resources of the continents of Africa, Asia, and Australia are unknown, but it has been shown in the foregoing that important deposits exist in South Africa, Australia, and India, and others are known, for instance, in China, Korea, and Japan. Moreover, having regard to the very large unexplored areas of these continents the existence of great reserves as yet undiscovered is very probable.

An ingenious method suggested by Sjögren and used by Eckel enables the iron-ore resources of the unknown continents of Africa, Asia, and Australia to be roughly estimated on the basis of the known resources of Europe and America. It is assumed that the resources of these countries are likely to be in some proportion to the areas, which, as the geological principles involved are the same in both cases, is not too unreasonable an assumption for the purpose in view. The ton-mile factor for the known continents works out at 1,646 tons per square mile. Applying this to the areas of the unknown continents we get a figure of 52,200 million tons for the reserves, which, added to the figure already obtained for Europe and America, gives a grand total of 84,000 million tons for the world's resources of commercial ore, in the sense of the present-day usage of the term.

On the whole adequate iron-ore supplies for the chief smelting centres of the world seem reasonably secure for a remote future. One fact, important for the makers of hæmatite steel, clearly emerges, and that is the relative scarcity of low-phosphorus ore. Excepting the great reserve of the very highest quality ore in Brazil the known reserves of low-phosphorus ore in the rest of the world only amount to some 1,740 million tons, the bulk of which is in the United States. The European resources of this class of ore are small and rapidly diminishing, and the claims on them are increasing. Spain is engaged in the development of a new iron and steel industry, and France will require a larger proportion of the North African ore. The British ironmaster, if he is to continue making hæmatite steel, will sooner or later be driven to seek his ore supplies outside Europe, and that indicates Brazil as the future main source of this class of ore.

REVIEWS.

Geochronologische Studien über die Spätglaziale Zeit in Südfinnland. By Matti Sauramo. Bulletin de la Commission Géologique de Finlande, No. 50. Helsingfors, 1918.

THE extension into Finland of Professor De Geer's method of obtaining the time-values of the stages of glacial retreat is an event well worthy of note. Dr. Sauramo's memoir deals with a considerable area of Southern Finland, both north and south of the great Finnish end-moraine known as the Salpausselkä. This region was largely submerged beneath the Late-Glacial or Yoldia Sea, the sedimentation in which was controlled by the flood waters from the retreating ice-sheet. The summer floods brought coarse sandy sediments; the winter cold reduced the glacial outflow, and the finer silts and clays were deposited at this season. There has resulted an annual lamination, which, strange to say, is so remarkably constant over wide areas that correlation from place to place is possible. The method of correlation introduced by De Geer, and applied by him with such spectacular success in Sweden, consists in drawing graphs along the axes of which are marked equal intervals representing the years, and erecting ordinates proportional to the thickness of the corresponding laminæ. The graphs of the different sections can then be compared by sliding them over one another until a coincidence is obtained sufficiently remarkable to establish identity.

The distances over which Professor De Geer effected these correlations were considerable, but it is more than surprising to learn that they can be carried out with a fair amount of success by direct comparison between sections some 200 miles apart on opposite sides of the Baltic. Seven sections, which the author of the paper under review ultimately fitted into the Finnish chronology, were sent to De Geer without localities or other clue to their identification. In the case of five of these he attempted a correlation with the Swedish record, but failed in two instances, with regard to one of which he had expressed doubt. The remaining three he placed in the correct relation to one another, in which they ultimately worked out in the Finnish record, and dated two of them with respect to the third with an error of less than five years in a thousand.

A study of the laminated clays corresponding to the stages of halt in the retreat, the most important of which are those marked by the inner and outer wreaths of the Salpausselkä, has rendered possible very accurate estimates of the duration of these stages, and brought out clearly the fact that they are periods of minimum summer ablation. The coarse summer zone, instead of forming the greater proportion of each year's sedimentation, is reduced to a negligible thickness or disappears altogether. The halt is thus obviously due to a drop in the summer temperature. A drop in the mean annual temperature cannot be deduced, but is probable. The important point is, however, that the halt is due to a temperature change, and not to a change in the precipitation or nourishment of the ice-sheet. This conclusion, which was also reached by De Geer in Sweden, is in itself very interesting, as it is obvious that a halt might be conceived to result from increased precipitation on the snowfields, producing an active thrust forward of the glacier front, and so balancing the marginal wastage. This, however, is only incidental to the main point, which it is the object of this review to emphasize, and which appears to be quite novel.

When the successive positions of the ice-margin are laid down on a map, or, more strikingly still, when the rate of retreat is plotted as a curve against the years, it becomes apparent that periods of halt in retreat were followed in nearly all cases by unusually rapid withdrawal, which gradually in the course of ten or fifteen years reverted to the normal rate characteristic of that stage of the retreat in general. This does not appear to have been due to excessive ablation, for the summer sediments in the laminated clays corresponding to these periods of rapid retreat have no exceptional thickness, and Dr. Sauramo draws the conclusion that during the cold period of the halt the ice-sheet had become thinner and so yielded more rapidly at its margin, once melting set in again.

Here, then, is additional light on the climatic condition of the halt-stages. Wastage was in progress during these periods, but was not, to any great extent, effected by the process of ablation. The ice surface was being lowered by some agent independent of ablation. There seems to be only one physical process that could account for such a remarkable phenomenon, namely, direct evaporation from the ice. This is, of course, well known to be physically possible, but it has certainly never been appreciated by geologists as an effective agency in glacial control. If it be now admitted as a result of this work of Dr. Sauramo's that such is the case, and that under sufficiently low conditions of temperature the wasting effects of direct evaporation may become comparable with those of ablation, or possibly exceed them, such a conclusion must modify all our notions of the growth and ultimate decay of ice-sheets.

W. B. Wright.

Contributions to the Knowledge of the Reptiles of the Karroo Formation. By Dr. E. C. N. van Hoepen. Annals of the Transvaal Museum, vol. vii, pt. ii, 1920.

THE author describes a new genus of Dinosaur from the Stormberg beds, and designates it *Aristosaurus erectus*. The animal was of small size and highly specialized. It shows adaptation to a bipedal mode of locomotion. The humerus is relatively much shorter than in other Anchisauridæ, the family to which it belongs.

In a second paper the author gives an account of two new genera of Theropoda; the bones of various known species are also described. Both papers are illustrated by excellent photographic reproductions.

F. H. A. M.

NOTES ON THE GEOLOGY AND IRON ORES OF THE CUYUNA DISTRICT, MINNESOTA. By E. C. HARDER and A. W. JOHNSTON. Bull. 660–A, U.S. Geol. Survey. pp. 26, with one map. 1917.

IN its geological features the recently developed Cuyuna range strongly resembles other iron-producing areas of the Lake Superior region. As elsewhere, the ores belong to the pre-Cambrian and present the same types of ore and country rock. The region is almost entirely covered by a thick mantle of drift, and it is of great interest to find that the discovery of iron-ore was entirely due to the existence of abnormal magnetic conditions. The occurrence of these abnormalities has long been known, but iron-bearing rocks were first proved by boring in 1904, and production began in 1911.

The rocks of the region, so far as known, are generally considered to be equivalent to the Virginia slate of the Mesabi district, but much more detailed work is required before this correlation can be regarded as proved. They have been invaded, after the principal metamorphism, by igneous intrusions, supposed to be of Keweenawan age; here and there are outliers of Keweenawan lavas and of Cretaceous sediments.

The iron-bearing rocks are folded into a complex series of N.E.–S.W. synclines and anticlines, forming a south-west extension of the Lake Superior synclinorium; the predominant dips in both limbs of the folds are to the south-east. The ore-bodies are exactly similar in general character to those of other ranges, showing a wide variation of type. The best quality yet known, a soft blue hæmatite from the Croft Mine, runs up to 67 or 68 per cent metallic iron, with very low phosphorus; the main part of the output consists of ore with 58 to 60 per cent iron and running up to 0·4 or 0·5 per cent phosphorus.

R. H. R.

SOUTH AUSTRALIA DEPARTMENT OF MINES. Mining Review, No. 31. Adelaide, 1920.

THIS half-yearly volume contains statistics of mineral production in the State for the whole of 1919. The general results appear satisfactory, considering the present industrial conditions. The serious diminution in the output of copper has been to a certain extent counterbalanced by the increase in iron-ore, which, for the first time, takes the leading place in value.

Among the special reports those of most general interest are the Second Summary Report on the utilization of Leigh Creek coal and an account of the manganese deposits worked by the Australian Manganese Company at Pernatty. A short account is also given of the Australian Slate Quarry, Willunga, which works a belt of slate of late pre-Cambrian or Lower Cambrian age, apparently of very good quality.

POLARIZED LIGHT IN THE STUDY OF ORES AND METALS. By F. E. WRIGHT. Proc. Amer. Phil. Soc., vol. lviii, 1919, pp. 410–47.

EXAMINATION OF ORES AND METALS IN POLARIZED LIGHT. By F. E. WRIGHT. Mining and Metallurgy, No. 158, 1920.

THE first of these papers gives an elaborate mathematical analysis of the theory of reflection of polarized light from polished surfaces of opaque substances, together with a description of various forms of optical apparatus adapted to determine the isotropic or anisotropic character of such substances; in certain cases the strength of the double refraction can be determined approximately. Methods involving the use of a bi-quartz-wedge-plate are the simplest, and have given the best results. In general, refractive indices cannot be ascertained on small polished random sections. The second paper contains a similar account of the practical application of these methods, with descriptions of the apparatus used by the author in his investigations.

REPORTS AND PROCEEDINGS.

EDINBURGH GEOLOGICAL SOCIETY.

March 17, 1920.—Mr. E. B. Bailey, M.C., B.A., F.R.S.E., F.G.S., President, in the chair.

1. "Notes on the Glacial and Post-Glacial Geology of the Dee Valley, from Balmoral to Aboyne." By Dr. Alex. Bremner, Aberdeen.

A glaciation map of the district was exhibited. In all 220 hitherto unrecorded striæ had been noted. There was no marked difference in direction between striæ due to the Ice Sheet and those due to the Valley Glacier. Lateral moraines and the terraces usually called "fluvio-glacial" were discussed. Of the latter there were many fine and hitherto unmapped examples. The effects of marginal drainage were very well exemplified in the district, and it was suggested that the truncation of spurs might be due in great measure to the cutting of marginal channels during the advance of glacier or ice sheet. Maps showing the river terraces were exhibited, and discrepancies between these and the Geological Survey maps pointed out. It was shown that there was no evidence for the former existence of a lake below Ballater.

2. "River Terraces." By Dr. Alex. Bremner, Aberdeen.

The contributions of Hugh Miller, jun., and Professor W. M. Davis to the theory of river terracing were reviewed. The former, who gave an adequate explanation of amphitheatre terraces (i.e. terraces having a front, on the whole, convex towards the river), and junction terraces, was not clear as to the mode of formation of what he himself called "the lateral terrace proper". Under that head he seemed to include (1) terraces with straight or slightly curved, nearly parallel front and back margins, and (2) terraces with strongly curved back margins concave towards the river. Professor Davis, elaborating an idea little more than suggested by Miller, propounded in his paper on "The River Terraces of New England" a satisfactory theory, not so much of terrace-formation as of *terrace-preservation.* "The lateral terraces proper" of Miller, particularly (2) above—the most difficult of all to account for—still required explanation. Such terraces had evidently been swept out in the first instance by pronounced and fairly persistent bends, to which the characteristic curves of their back margins was due. In the case of the Dee, the river was not withdrawn by short-circuiting across the necks of the spurs within the bends; for the slope of such terraces was, on the whole, towards, not away from the present course of the river. The conditions determining the formation of river islands and their incorporation in the flood-plain were discussed in detail. It was pointed out that every terrace of any extent along the Dee was traversed by a larger or smaller number of anastomosing hollows, plainly former channels of the river or of branches of it; and that terraces of all types had been built up by the accretion of island to island through the desertion and subsequent partial obliteration (by flood-loam, etc.) of secondary channels. The process was shown to have illustrations elsewhere; and the principle involved was no doubt of wide application in the case of rivers of fairly steep gradient whose flood-plain, like that of the Dee, was practically coextensive with their meander belt.

3. "A Rhomb Porphyry Boulder from the Glacial Deposits at Bay of Nigg, Aberdeen." By Dr. Alex. Bremner, Aberdeen.

The Rhomb Porphyry—a boulder weighing 32 lb.—was found 15 feet above H.W.M.O.S.T. in a boulder-bed, far too coarse to be called a gravel, underlying the Lower Grey Boulder Clay of the Aberdeen district (see Trans. Edin. Geol. Soc., vol. x, pt. iii, p. 345). The probable ways in which it might have reached the place where it was found were discussed, and the resemblance between the glacial sequence at Bay of Nigg and that on the Yorkshire coast was pointed out. This was the first record of the occurrence of a Scandinavian boulder, *in situ* in glacial deposits, on the mainland of Scotland.

INSTITUTION OF MINING AND METALLURGY.

October 21, 1920.

"The Origin of Primary Ore Deposits." By J. Morrow Campbell, D.Sc., F.G.S.

The author commences at the period when the outer silicate shell of the earth was molten. The primeval magma is regarded as having been practically homogeneous and containing about 60 per cent of combined silica. All water was then in the atmosphere. As temperature fell water and oxygen were absorbed, crust-formation, foundering, and resorption went on for a long period, producing a flat temperature-gradient in the liquid. When the crust became permanent, granite developed, and below it basaltic magma long remained liquid. At this stage the isostatic balance was adjusted. Ore-minerals in large quantity were given off at the surface of the granite, were denuded, and dispersed in sediments and solution. This, with subsequent absorption by basaltic magma, is assumed to have been instrumental in causing the present erratic distribution of primary ores.

Magmatic differentiation is regarded as having been caused by the agency of silicic acid—silicon combined with hydroxyl—which extracts potash alumino-silicate, producing a solution immiscible with and lighter than a melt of basic felspars and femic minerals.

Evidence regarding the existence of silicic acid in magmatic liquids and elsewhere in nature is recited.

The ultimate result of the action of water on rock magmas is that silicates are completely removed and a residue of ore-minerals—magnetite, etc.—left.

Vein fissuring is held to have been brought about in and above batholiths by the expansive force due to the increase in solid specific volume of various elements. The effect of this force appears in waves as successive series of fissures. These developed very rapidly, were instantly filled with magmatic mother-liquor, and quickly sealed by the deposit of solids therefrom. It is argued that primary ore-minerals passing up from magmas to veins do so in silicic acid solution; that their deposition is determined both by loss of heat and reduction of pressure; and that there are definite but narrow limits of temperature between which each ore-mineral develops.

Reasons are given why the pneumatolytic origin of tin and tungsten ores should be rejected.

CORNISH INSTITUTE OF ENGINEERS.

September 16, 1920.

"On the Characters of some Cornish Veinstones." By the President, Mr. E. H. Davison.

The paper gives the results of the examination of a number of Cornish lodes. Those not at present being worked were represented by isolated specimens from known points in the lode, while the lodes now working were systematically sampled down the dip.

The methods employed included microscopic and microchemical examination as well as in some cases mechanical analysis. It was considered that three types could be recognized which were related to the surface of the nearest granite mass.

1. Quartz-wolfram lodes. Little cassiterite, sulphides, or tourmaline, characteristically no chlorite. Upper level of tin and tungsten zone. Occurring in the slate or just in the granite, at or near the crest of the mass.
2. Quartz-chlorite-wolfram-cassiterite-mispickel lodes. Chlorite predominant over tourmaline. Cassiterite usually more than wolfram. Sulphides common. Middle of tin-tungsten zone.
3. Quartz-tourmaline-cassiterite lodes. Tourmaline predominant. Wolfram absent. Sulphides absent or subordinate. Lower part of tin-tungsten zone. Occurring in depth in the granite.

It was also noted that if wolfram was present in the lode, copper was absent or subordinate. The detailed microscopic characters of the veinstones were given in tabular form at the end of the paper.

CORRESPONDENCE.

PHYSIOGRAPHIC RELATIONS OF LATERITE.

Sir,—In reply to Professor W. M. Davis's inquiry in the September number of this Magazine, I should in the first place explain that my paper on Lateritization in Sierra Leone was concerned essentially with the chemical and mineralogical changes undergone by the different rocks of the country in the course of their transformation into laterite, and only to a minor extent with the relation of the laterite to surface forms and physiographic old age. Nevertheless, I am indebted to Professor Davis for directing my attention to several additional points of interest.

In Sierra Leone, as elsewhere in the tropics, laterite is in general best developed on surfaces of gentle slope or low relief, as the following examples from different parts of the country will show:

1. *The Coastal Plain.*—This plain, which along the inner margin rises to a height of about 400 feet above sea-level, consists of sediments, probably of Pleistocene age, which are still in process of lateritization. Locally on these sediments there occur large bare sheets of laterite, free from vegetation and soil, similar to those described by Mr. Morrow Campbell,[1] and explained by him as due to rapid growth of highly ferruginous laterite; this laterite diminishes the fertility of the soil, which, losing the protection of the dying vegetation, becomes gradually washed away by the torrential rains.

2. *The Crystalline Rocks of the Lowlands.*—These rocks under the following conditions are in general deeply kaolinized and lateritized—

(*a*) Where rising as low hills above the sediments of the coastal plain:

(*b*) On those undulating areas in which the plain merges along its

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[1] "Laterite, its Origin, Structure, and Minerals": *Mining Mag.*, vol. xvii, 1917, p. 178.

inner margins into the uplands. Where, on the other hand, the change from coastal plain to upland or plateau country is abrupt, and the relief of the crystalline rocks is considerable, altered rocks are rarely seen and laterite is practically absent.

3. *Ancient Sedimentary Rocks of the north-west corner of the Protectorate.*—These sediments, which do not depart greatly from the horizontal, are capped by a great thickness of dolerite. The sediments and the dolerite, together with the underlying crystalline rocks, form a great scarp over 2,000 feet in height. Laterite is well developed on the dolerite, but it is now undergoing extensive erosion.

4. *The Norite of the Colony.*—Laterite is best developed on certain ancient platforms carved into the mountain mass.

5. *The Great Plateau forming the north-eastern part of the Protectorate.*—Over a large portion of this plateau, away from the margins, conditions are very different from those considered above, because an extensive area of the crystalline rocks, which make up the plateau, is overlain by a sand formation,[1] which so far has not been observed in any other part of the country. This sand formation locally attains a thickness of more than 300 feet. It is undergoing extensive erosion, which has resulted in the central areas of the sand-sheet in the carving of deep valleys, at the bottoms of which the crystalline rocks are again exposed; towards the margins of the sheet the sands appear as numerous flat-topped and conical hills, and finally, along the limits of the sheet, the sands form only a few caps on the crystalline plateau. This plateau is generally well-defined, although it is for the most part trenched by steep-sided valleys; locally erosion has proceeded much further. The upper surface of the main sheet of the sands consists of a series of plateaux, which do not differ greatly in height. Laterite is developed on the sands and on the crystalline rocks as follows:—

(*a*) The Sands.—The laterite forms a continuous crust, rarely exceeding 2 feet in thickness, on the surfaces of the plateaux and on the flat-topped hills. The laterite of the higher plateaux must be regarded as older than that of the lower. On the sides of the hills laterite does not occur except as fallen blocks, and on the low ground between the hills it is developed only as occasional thin patches of gravel.

(*b*) The Crystalline Rocks.—Laterite has very rarely been observed on these rocks within the limits of the sand formation. The sands, often containing near their base fragments of the country rocks, frequently rest upon a perfectly fresh surface; elsewhere they rest upon a surface which is variably, but not deeply, kaolinized. Sometimes, far beyond the present limits of the sand-sheet, there occur extensive flat or gently convex areas of the crystalline rocks, chiefly

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[1] I have recently given a brief description of these sands and the ferruginous laterite capping them; see "Primitive Iron-ore Smelting Methods in West Africa": *Mining Mag.*, October, 1920.

granites; these areas, which are quite bare except where covered by occasional clumps of grass, are remarkable in being quite fresh, showing no signs of weathering or any other kind of alteration. The absence of laterite on such surfaces has been explained by Mr. Morrow Campbell, who has paid much attention to the conditions under which rocks become kaolinized and lateritized in the tropics. This writer considers that crystalline rocks must be altered before they can be lateritized, and also that the alteration necessary, generally kaolinization, can be produced only when the rocks have been for a long time continuously in contact with vadose water, i.e. in the zone of permanent saturation.[1] Accordingly, the fresh surface rocks referred to above, not having been subjected to such conditions, remain unlateritized.

F. DIXEY.

UNIVERSITY COLLEGE, CARDIFF.
October 4, 1920.

AN UNDESCRIBED SPECIES OF *TROCHILIOPORA.*

SIR,—I desire to draw attention to a band of Chalk in Sussex, about 10 feet thick, near the base of the zone of *Micraster coranguinum*, in which an undescribed Polyzoon belonging to the genus *Trochiliopora* is very common. As this fossil appears to be confined to the said band of Chalk, and also owing to its abundance, it has proved to be a very useful local zonal guide fossil. The exact position in which it occurs in the *Micraster coranguinum* zone is as follows:—

Lower fourth of zone of *Micraster coranguinum.*	Strong *M. coranguinum* tabular flint band.
	Chalk, about 35 feet.
	Chalk with *Trochiliopora* sp., 10 feet.
	Chalk, about 17 feet.

Chalk of zone of *Micraster cortestudinarium.*

I propose to call the 10 feet of chalk referred to "the *Trochiliopora* bed".

The genus *Trochiliopora* has been described by Professor J. W. Gregory in the GEOLOGICAL MAGAZINE, 1909, p. 65, and also in the British Museum Catalogue of Cretaceous Bryozoa, vol. ii, p. 265. The species above referred to resembles *T. humei*, Gregory, but its body tapers to a much finer stem than the stout blunt stem of the latter species.

The *Trochiliopora* bed is rich is Polyzoa, it having yielded some rare and interesting forms.

CHRISTOPHER T. A. GASTER.

LEWES, SUSSEX.
October 4, 1920.

GEOLOGY OF THE NINGI HILLS.

SIR,—Major Williams' paper on the geology of the Ningi Hills of Nigeria in the October number is very welcome. It indicates not

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[1] Morrow Campbell, op. cit., p. 123.

only an increasing interest by the mining community in the geology of the Nigerian tinfields, but also, I hope, an increasing disposition to publish geological observations thereon. Major Williams, however, will agree that in view of local controversies it is important that facts and conclusions should be correctly stated and deduced, and I may therefore perhaps be allowed to make the following remarks upon his paper.

Major Williams makes no mention of the fact that I mapped and described in 1911, in my "Geology and Geography of Northern Nigeria", the younger riebeckite-granites of Ningi, Kila, and Fagam, with which a portion of his paper is concerned. Of the country between Buji and Ningi, I have little personal knowledge, but from what I have gathered in conversation with capable observers who have repeatedly traversed it, and from what I know of the adjoining parts of the tinfields, I feel sure that there are there not extensive outcrops of an older riebeckitic Sabon Garri granite, but a number of outcrops of younger riebeckite-granite projecting through older micaceous gneisses of various types. In spite of the assertion to the contrary in the appendix on p. 446, the petrographical descriptions do not confirm the hypothesis of an older series of intrusions "specially characterized by perthite, riebeckite, and ægirine". Of the sections quoted in support Nos. 106, 108, 110, C.C. 3, and C.C. 4 contain no perthite, riebeckite, or ægirine; No. 113 is valueless as evidence; No. 115 is said on one page to be "slightly crushed" and on another to show "no sign of crushing" and to belong "to the younger series", while Nos. 100 and 105 are simply sections of normal younger granite.

It would also be interesting to know how Major Williams arrives at his belief that the younger granites of Nigeria are of Mesozoic age. It may be on account of the relative freshness of their outcrops, as in the case of the Tertiary (?) gabbro dyke of Keffi Filani. In any case the distinction of Archæan and Mesozoic soda-granites in Nigeria cannot be considered established, while the generalization that "tin is only found in granites that contain riebeckite" is true only in the sense that tinstone is associated with the younger granites, which may or may not carry riebeckite.

J. D. Falconer.

London.
October 13, 1920.

OBITUARY.

Sven Leonhard Törnquist, Ph.D., F.M.G.S.

Born March 6, 1840. Died September 6, 1920.

The study of Graptolites has in the last few years suffered the loss of some of its veteran workers, and to the names of Hopkinson and Lapworth must now be added that of the Swedish geologist, S. L. Törnquist. Born at Uddevalla in 1840, he proceeded in due course to the University of Lund, where Otto Torell was lecturing on geology, and in 1865 obtained the degree of Ph.D. on the strength of a paper on the Ordovician beds of Fågelsång. In 1867 he became reader at the secondary school of Gefle, and in 1882 was transferred to Lund, and at both places devoted his leisure to the study of the Ordovician and Silurian rocks in the neighbouring districts. In 1892 his careful researches on the organization of Graptolites by the method of grinding down specimens preserved in pyrites shed much light on the structure of these fossils. He was elected Foreign Correspondent of the Geological Society of London in 1893, and became a Foreign Member in 1900. The title of Professor was conferred on him in 1902, and in 1905 he resigned his teaching duties, but continued to reside in Lund till his death, which took place after a few days' illness. Up to the last he preserved his vigour of mind and body, and his kindly nature, ever ready to assist his fellow-workers with his wide experience and knowledge, endeared him to all his friends, while his numerous papers on the Lower Palæozoic beds and faunas of Dalecarlia and Scania form a valuable contribution to science.

James Somerville Geikie.

Born 1881. Died 1920.

Mr. J. S. Geikie, son of Professor James Geikie and nephew of Sir Archibald Geikie, died recently in Borneo from septic pneumonia, at the early age of 39. As the inheritor of a good share of the ability of his family, he gave promise of a highly successful career as a mining engineer, having already carried out technical work of much importance at the Bau gold-mine in Sarawak and elsewhere. His greatest interest, however, was in geology, in which science he gave promise of excellent future work. His loss will be sincerely mourned by many to whom he had endeared himself by the simplicity and strength of a fine character.

Charles Clifton Moore, F.I.C.

Born 1862. Died 1920.

Mr. C. C. Moore, who died on August 11 last, was well known in both scientific and commercial circles in Lancashire and Cheshire. He was for some time engaged in chemical work at St. Helens, and for thirteen years with Brunner, Mond & Co., Ltd. Afterwards he founded the important firm of Charles Moore & Co., Ltd., chemical manufacturers. In spite of a busy commercial life, he was always much interested in geology, and was President of the Liverpool Geological Society. His published papers, in the *Proceedings* of that Society, chiefly dealt with the volume-relations of rocks, and comprise many very complete analyses of rocks As a man of wide knowledge and genial disposition he will be much missed by those who enjoyed his acquaintance.

All Communications for the EDITOR should be addressed to
R. H. RASTALL, Esq., M.A., Christ's College, Cambridge.

All letters for Dr. H. WOODWARD, F.R.S., may be sent to
Tudor Cottage, Clay Hill, Bushey, Herts.

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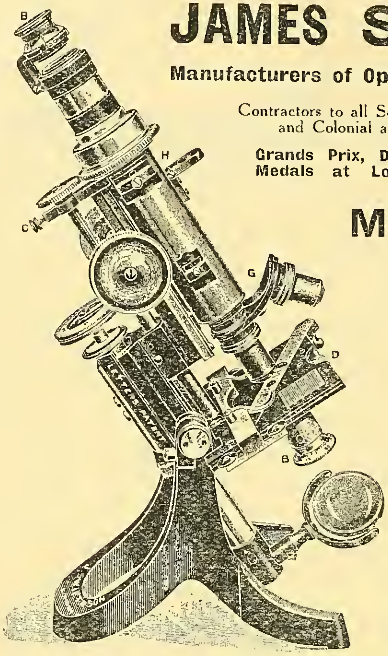

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OSWALD (Felix), D.Sc., F.G.S. **A Geological Map of the Caucasus.** With explanatory text. Compiled from the latest sources. Scale 1: 1,000,000 (15·78 miles = 1 inch). 15*s*. The geological formations and the igneous rocks are clearly displayed in twenty different colours. The glaciers are also indicated. All heights are given in English feet, and the latest railways have been inserted. The pamphlet of explanatory text gives a brief account of the main physical divisions of the Caucasus, followed by a detailed description of the successive geological horizons with their characteristic fossils. Special care has been taken to indicate the exact position in the geological series at which petroleum occurs in the Caucasian oil-fields.

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THE
GEOLOGICAL MAGAZINE
VOLUME LVII.

No. XII.—DECEMBER, 1920.

EDITORIAL NOTES.

THE senior Editor, Dr. Henry Woodward, F.R.S., who founded the GEOLOGICAL MAGAZINE in 1864, completed his 88th year on November 24, 1920, and is still enjoying good health and taking a warm interest in the Magazine. He played an active part in the preparation of the present issue, No. 678, the concluding number of the 57th volume.

* * * * *

WE learn that the following promotions have been made in the Geological Survey: Mr. J. Allen Howe and Dr. Walcot Gibson to be Assistants to the Director, the former in London and the latter in Edinburgh; Mr. Henry Dewey and Mr. Bernard Smith to be District Geologists. We hope to give at an early date further particulars as to future developments of the work of the Survey.

* * * * *

MR. C. P. CHATWIN, F.R.M.S., who so ably filled the office of Librarian at the Geological Society, Burlington House, and was made Demonstrator in Geology at the University of Liverpool in 1919, under Professor P. G. H. Boswell, has, we learn, just been appointed Assistant Palæontologist to the Geological Survey at the Jermyn Street Museum under Dr. F. L. Kitchin, M.A., F.G.S.

* * * * *

ABOUT three hundred Upper Tertiary and Recent Gasteropods—labelled by the donor in illustration of his monograph published by the Palæontographical Society on the "Pliocene Mollusca of Great Britain" (vol. i)—have been presented to the Geological Department of the British Museum (Natural History) by F. W. Harmer, Esq., M.A., F.G.S.

* * * * *

BY the death of Dr. Allen Sturge, M.V.O., March 27, 1919, the Department of British Mediaeval Antiquities in the British Museum, Bloomsbury, received the finest private collection of stone implements in existence. When packed, the collection, including the exhibition and storage cases that formed part of the bequest, weighed about 25 tons, and was conveyed by road from Icklingham Hall, Suffolk, to London during the summer.

The north-west angle of Suffolk is abundantly represented by specimens excavated from clay and gravel or more frequently picked up on the surface, to a large extent by Dr. and Mrs. Sturge; and the series from Warren Hill, High Lodge, and Elveden are of the highest importance. Hundreds of Drift implements come from gravel pits in the Thames valley near Dawley (Hayes, Middlesex), and quantities from other well-known sites, such as Swanscombe, Farnham, Dunbridge, Southampton, Savernake Forest, Bedford, and Broom. A large quantity had been acquired from Mr. Worthington Smith, mostly found in north-east London; and other collections made by Canon Greenwell and Messrs Greenhill, Allen Brown, Simeon Fenton, Robert Elliot, and Thomas Bateman were incorporated.

The foreign section is also very rich, the entire contents of many French caves having been obtained from M. Reverdi. Chief among such specimens is a Solutré blade from the hoard found at Volgu in the Dépt.-Saône-et-Loire; and the French Drift and Neolithic series are well selected. Scandinavia, Western and Southern Europe are adequately represented, and there is a large collection from the Swiss lake-dwellings. An ample Egyptian series contains some of the best flint work known, and there are hundreds of excellent examples from America, South and East Africa, and Madras.[1]

* * * * *

We have received a copy of the first number of a new periodical, *The Mining Electrical Engineer*, which is to be the official journal of the Association of Mining Electrical Engineers; this body has now had a useful existence of eleven years, and it has naturally felt the need of a definite organ of opinion, to place before the world a record of the work done by the Association, and to collect information as to the general progress of electrical engineering as applied to mines. The contents of this number are naturally mainly of a technical nature, and there is not very much bearing on geological questions. Nevertheless, the connexion between mining and geology is so close that we welcome this addition to the literature of the subject. The general get-up of the journal, which is profusely illustrated, is excellent, and we wish it a successful career.

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At last the Geological Society of London (following the earlier example of the Geologists' Association) have resolved to expend a sum of £500 from the invested funds of the Society to provide the means necessary to carry on scientific publications, and a special general meeting will be held on December 1, 1920, at 5.15 p.m., in order to obtain sanction to carry out this object. Having regard to the great increase in the cost of printing and paper since the War, no Fellow of the Society can doubt the wisdom of this recommendation of the Council. In addition to the

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[1] A summary description in French of the whole collection was printed for the meeting of the International Congress of Anthropology and Prehistoric Archæology which met at Monaco in 1906.

above proposed provision of funds, Fellows are reminded that, after the completion of vol. lxxvi (1920), they will not be entitled to receive the Quarterly Journal regularly unless a subscription at the rate of 10*s.* per volume is paid in advance, along with their annual contribution to the Society. Those Fellows who do not require the complete series can obtain separate parts at the price of 3*s.* each, if applied for within one year of the date of issue.

* * * * *

We have been informed that a proposition is on foot—between the Trustees of the British Museum and the Treasury—to revise the present scale of salaries for assistants now entering the British Museum so as to render them more in accordance with those in other branches of the public service and remove the difficulty which at present prevents many able men, with University training, from offering themselves as candidates for vacancies now actually existing in the staff of the Natural History Branch. We trust that, in addition to a *larger initial salary* about to be offered to *new men* who may apply for these vacant posts, the salaries of those older men now upon the staff will *also be increased* so as to render them more in in accordance with the changed circumstances of living in 1920–1, from which *all persons* with *fixed pre-War incomes* are suffering mostly without hope of relief.

* * * * *

The ninety-seventh annual report of the Whitby Literary and Philosophical Society contains, among other matter of local interest, an excellent article by Mr. J. T. Sewell, entitled "Notes on the Geology of Whitby Sands". The rapid erosion of the boulder-clay cliffs west of Whitby is known to many, and even the writer of the present note, in the course of a not very long life, has witnessed some remarkable changes. But the variations that have taken place on the beach are perhaps of equal interest, and much more difficult to detect. Mr. Sewell has made minute and detailed observations on the spot for thirty years, recording any exposure of rock due to temporary removal of the sand and gravel by tides, waves, and currents, especially during storms, and he has thus accumulated an unrivalled acquaintance with the details of this particular stretch of foreshore. Some useful information was also acquired during the building of the pier extensions. The results are presented in a couple of large-scale maps, 12 inches to the mile, which show, among other things, that both piers rest on Lias shale. It is also very interesting to find that Mr. Sewell's observations lead him, with apparently good grounds, to doubt the existence of any fault in Whitby Harbour. This paper is an excellent example of the way in which the long-continued and careful observations of a geologist living on the spot may serve to correct the hasty generalizations of those not possessing the local knowledge so necessary in work of this sort.

ORIGINAL ARTICLES.

Sedgwick Museum Notes: Notes on the Genus *Sphaerocoryphe*.

By W. B. R. King, M.A., F.G.S.

(PLATE XIII.)

DR. F. R. COWPER REED, in a paper entitled "Notes on the Affinities of the Genera of the Cheiruridæ",[1] points out that *Sphærocoryphe* belongs to the Cheiruridæ, while *Staurocephalus*, which has at first sight some superficial likeness to it, belongs probably to the Encrinuridæ.

Some additional light has been thrown on to this subject by the recent discovery of a complete specimen of *Sphærocoryphe* in the Ashgillian beds of Norber Brow, Austwick, near Settle, by Mr. T. H. Thorneycroft, of Pembroke College, Cambridge. Mr. Thorneycroft has kindly presented the specimen to the Sedgwick Museum. The specimen, which is referable to *Sphærocoryphe thomsoni* Reed, although somewhat compressed and crushed laterally by the cleavage, possesses all the characteristics of the species, but the chief point of interest is that the hypostome is preserved in place, and was found inside the swollen frontal part of the glabella. The hypostome and material filling the glabella broke away and remained on the "cast" side of the specimen. This appears to be the first hypostome definitely referable to a specimen of this genus. The hypostome of *Staurocephalus* is also rare, but one is figured by Salter,[2] and this is preserved in the British Museum.

Novák[3] has shown that hypostomes are of considerable use in determining the family relationship of various genera, and his contention seems to hold good in this case also. It may be as well, therefore, to describe the hypostome of *Sphærocoryphe thomsoni* which Mr. Thorneycroft found associated with the complete individual and compare it with that of other Cheirurids and *Staurocephalus*.

The hypostome is slightly smaller than the swollen frontal part of the glabella, since it was found pushed into it without contortion. The general outline is square, formed of a large central, raised, elliptical portion, surrounded by a deep wide groove and raised narrow margin. The anterior margin is not well preserved in this specimen, but appears to be slightly curved in outline and to

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[1] Geol. Mag., 1898, pp. 206–14.

[2] "British Trilobites": Palæont. Soc., 1864–83, pl. vii, fig. 17.

[3] Ottomar Novák, "Studien an Hypostomen böhmischer Trilobiten": Kön. Böhm. Gesellschaft der Wissenschaften, Prag, 1879–86.

rise sharply from the groove which separates it from the central raised portion. At the lateral extremity of the frontal ridge the groove reaches the margin of the hypostome, thus forming a break in the raised marginal ring. This also makes two notches in the general square outline. The lateral margins are raised and thickened, particularly just below the notch mentioned, above and at the posterior angles. The angle between the lateral and posterior parts of the margin is sharp and about 90 degrees. The central part of the posterior border is bent slightly towards the centre of the hypostome. There are indications of a small pit in the groove opposite the posterior edge of the notch in the position shown in the restoration. The surface of the hypostome is finely granulated, as shown by its "cast".

From the restoration it will be seen that the hypostome is similar in type to the typical Cheirurid hypostome, such as that of *Cheirurus bimucronatus* Murch.[1] or Barrande's figures of Cheirurid hypostomes in his *Systême Silurien*,[2] but the hypostome which shows more points in common than any other is that of *Deiphon forbesii* Barr.[3] In *Deiphon* there is the same central spherical raised portion separated by the marked groove from the raised marginal ring. The general outline is almost exactly the same in each case. In *Deiphon* the granulations on the central portion are more marked (*vide* Salter's figure) than in *Sphærocoryphe*, but this may well be a result of the development of one from the other. Dr. Cowper Reed [4] has shown that the various characteristics of *Deiphon* appear to be developed from the rather less specialized form which is found in *Sphærocoryphe* and the discovery of the hypostome, which has been shown to be of great use in deciding family relationships, certainly bears out his views.

Turning now to the hypostome of *Staurocephalus*, an examination of the specimen in the British Museum figured by Salter [5] shows several points which are not brought out very clearly in the figure. Firstly the specimen has suffered considerably during the development to which it has been subjected. The result is that the posterior part has been broken away to a great extent. The two knobs about the centre of the hypostome are clearly shown in the figure, but on the right-hand side, looking at the hypostome, there is clear evidence that once the anterior part of the hypostome extended laterally in the form of a wing. Just behind this wing there is a slight ledge, which may be a fragment of a border on a lower level. If this really be the case then the hypostome of *Staurocephalus* would consist of a flattish margin with marked wings and a sharply

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[1] Salter, "British Trilobites": Palæont. Soc., pl. vi, fig. 11.

[2] Barrande, *Systême Silurien*, vol. i, pls. xli–xlii.

[3] Salter, "British Trilobites": Palæont. Soc., pl. vii, fig. 10; and Lindström, "Forteckning på Gotlands Siluriska Crustacéer opersigt. af k. Vetenskaps-Akadeniens Förhandlinger," 1885, No. 6, p. 37, and pl. xv, fig. 18.

[4] F. R. C. Reed, GEOL. MAG., 1898, p. 211.

[5] Salter, op. cit., pl. vii, fig. 17.

rising blunt triangular raised central portion possessing two marked knobs, rather below the centre. The anterior part is nearly flat, with only slight undulations. The general outline of the whole would be triangular.

It is difficult to find any family with a similar type of hypostome; certain it is that it is far from the Cheirurid type, but it must also be admitted that very little resemblance can be seen between it and the normal Encrinurid type, with its peculiar and striking central tongue-like anterior protrusion.

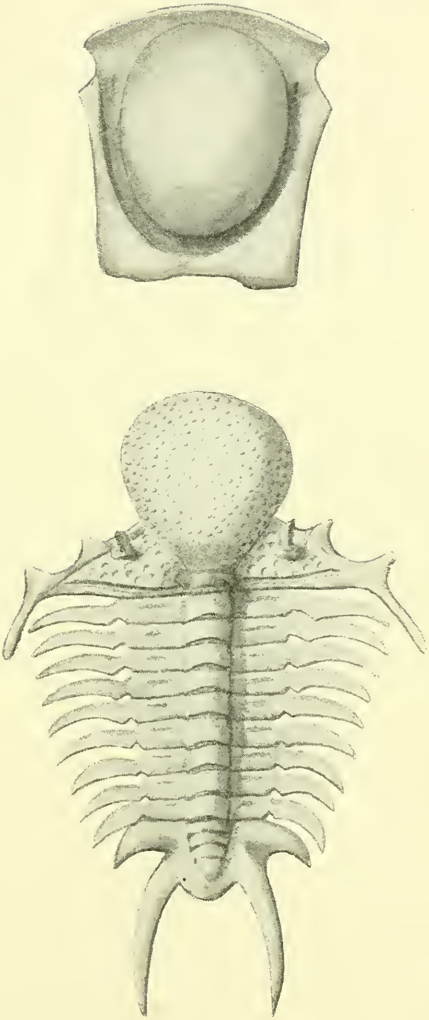
A study of the hypostome of *Staurocephalus* therefore confirms the view that it should be removed from the Cheiruridæ, but does not seem to indicate that it should be put into the Encrinuridæ unless it branched off from some very early form before the characteristic frontal tongue was developed. However, all figures of *Encrinurus* or *Cybele* which show the hypostome have this tongue well developed. If, however, *Staurocephalus* is barred from both the Cheiruridæ and Encrinuridæ it is difficult to find a family in which to place it.

It may not be out of place here to study some points in connexion with the general structure of *Sphærocoryphe* and forms of similar general appearance. As the specimen from Norber Brow, although much compressed laterally, shows all the details of the ornamentation clearly, it was decided to draw a restoration, taking the details largely from the Norber Brow specimen, but the general outline from some of the Girvan specimens, especially from a nearly complete specimen in the British Museum (No. I. 16047).

The restoration (Plate XIII) is intended to bring out some of the more striking features of *Sphærocoryphe thomsoni* Reed. A detailed description of the species is given by Dr. Reed in his Girvan Trilobites monograph.[1] To this there is nothing to add, but a point which occurs to a worker on Lower Palæozoic Trilobites, is that when identifying specimens of this species it should be borne in mind that the usual type of pygidium is that shown in the restoration,[2] with apparently one short and one long spine on each side of the axis.

From the foregoing notes there would seem to be little real similarity between *Sphærocoryphe* and *Staurocephalus*; the only cause of the confusion which arose between these two genera was the marked swelling of the frontal part of the glabella. This swelling is present in several other genera, particularly *Deiphon*, probably a direct descendant of *Sphærocoryphe*, and also in the peculiar Australian genus *Onycopyge* described by Dr. H. Woodward.[3] Even some species of *Phacops* (s.s.), for instance *P. cephalotes* Corda from Étage G. of Bohemia, show considerable swelling of the frontal parts of the glabella. The origin and use of this peculiar line of development seems to be rather obscure, but the subject is touched upon by Dr. L. Dollo [4] in regard to *Deiphon*, where he attributes the extremely modified form to external influences connected with its mode of life.

N.B.—For footnotes see p. 538.



RECONSTRUCTION OF SPHÆROCORYPHE THOMSONI REED.

[*To face p.* 534.

North American Species of the Brachiopod *Etheridgina.*

By D. K. Greger, Fulton, Missouri.

(PLATE XIV.)

THE series of minute, adherent species of Brachiopoda brought together in the following discussion are usually assigned by American palæontologists to the genus *Strophalosia*, but recent writers have come to recognize the fact that, in America at least, the genus *Strophalosia* is a polyphyletic group. Dr. Stuart Weller, in his monograph on the Mississippian Brachiopoda (1914), all but recognizes the generic value of these minute shells when he points out the lack of harmony in the series of forms which he places in the genus *Strophalosia.*

Of the five American species here grouped under Oehlert's excellent genus *Etheridgina*, the *Strophalosia scintilla* of Beecher bears the closest resemblance to the genotype, *Productus complectens* Etheridge. *S. scintilla* is abundant in the fauna of the Louisiana Limestone (Kinderhookian) of Eastern Missouri, and my collection contains over three hundred examples in various stages of development—from minute spats 0·4 mm. in diameter to mature shells, the average size of which seldom exceeds 2·5 mm.

Recently, through the kindness of a Scottish correspondent, eight well-preserved specimens of *Etheridgina complectens* (Etheridge), from Fife, were placed in my hands for study and illustration, and an examination of this material brings out the following facts—the presence of a cardinal area, a covered delthyrium, attachment of the pedicle valve by cementation over the greater part of the visceral area, instead of at the beak as in the true Strophalosias, and that the clasping propensity of the spines is more apparent than real.

While fully appreciating the necessity of correct application of a generic term, our study of these minute forms leads to the conclusion that it better serves the purpose of classification to group under the genus *Etheridgina* the following so-called Strophalosias from American strata.

Genus ETHERIDGINA Oehlert.

1877. *Etheridgina*, subgenus of *Productus*. Genotype *E. complectens.* In Fischer, Manuel de Conchyliologie, p. 1278.

Etheridgina complectens (Etheridge). (Pl. XIV, Figs. 1–3.)

1876. *Productus complectens* R. Etheridge, jun., Quart. Journ. Geol. Soc., vol. xxxii, p. 462.

1878. *P. complectens* R. Etheridge, jun., op. cit., vol. xxxiv, p. 498.

From the published figures of this species I have reproduced two of the figures of Mr. Etheridge, Fig. No. 1 from his paper of 1876 and Fig. No. 2 from the 1878 paper, since they best illustrate the characters of the species as it is generally found. I have also selected for illustration, from the Fife specimens in hand, an example attached to a fragment of gastropod shell, since this specimen shows both valves, in their natural position, and other features in an excellent manner.

ETHERIDGINA RADICANS (Winchell). (Pl. XIV, Figs. 4–8.)

1866. *Crania radicans* Winchell, Geol. Rept. Lower Peninsula of Michigan, Appendix, p. 92.
1890. *Strophalosia radicans* Beecher, Amer. Journ. Sci., vol. xl, p. 240, pl. ix, figs. 14–17.
1892. *S. radicans* Hall & Clarke, Palæont. New York, vol. viii, pt. i, pl. xv*b*, figs. 27–30.

I have seen but three imperfectly preserved examples of this species, from the limestones of the Hamilton (Devonian) from the vicinity of Alpena, Michigan. Their condition is such that specific characters are almost obliterated. Beecher and Hall & Clarke have, however, given ample illustration of the characters of the species, and figures of these authors are here reproduced.

ETHERIDGINA KEOKUK (Beecher). (Pl. XIV, Figs. 9–11.)

1890. *Strophalosia keokuk* Beecher. Amer. Journ. Sci., vol. xl, pp. 244–5, pl. ix, figs. 18–24.
1892. *S. keokuk* Hall & Clarke, Palæont. New York, vol. viii, pt. i, pl. xvii*a*, figs. 5–7.
1914. *S. keokuk* Weller, Mississippian Brachiopoda, Monogr. No. 1, Illinois Geol. Surv., p. 145, pl. xviii, figs. 17–18.

This species is fairly abundant in the Crawfordsville Shale (Mississippian) of Indiana, most frequently found attached to *Platyceras* and corals, also occasionally found on the columns of crinoids, which are abundant in the shale. I have reproduced the original figures of Beecher and one by Hall & Clarke.

ETHERIDGINA SCINTILLA (Beecher). (Pl. XIV, Figs. 12–14.)

1890. *Strophalosia scintilla* Beecher, Amer. Journ. Sci., vol. xl, pp. 243–4, pl. ix, figs. 10–13.
1892. *S. scintilla* Hall & Clarke, Palæont. New York, vol. viii, pt. i, pl. xv*b*, figs. 32–4.
1908. *S. scintilla* Rowley, Missouri Bureau of Geol., vol. viii, 2nd ser., p. 76, pl. xvii, figs. 26–9.
1914. *S. scintilla* Weller, Mississippian Brachiopoda, Monogr. No. 1, Illinois Geol. Surv., p. 144, pl. xviii, figs. 19–23.

The youngest example of this species I have found is subcircular, and has a diameter of 0·4 mm., the brachial valve is gently convex, hinge-line and beak very obscure. Specimens of 1·0 mm. in diameter are slightly transverse, with well-defined hinge-line and less obscure beaks; the brachial valve generally exhibits one or two well-defined growth-lines. At this stage in the development of the shell the pedicle valve is closely cemented to the host, the hinge-line and beak only being raised above the level of the front and sides However, upon reaching maturity, or approximately 2·5 mm. in diameter, a trail begins to form by the abrupt upward deflection of the anterior margins of the pedicle valve and a thickening or piling up of the shell layers along the margins of the brachial valve. With the upward deflection of the anterior and lateral margins of the pedicle valve, a number of irregular, hollow, spine-like digitations form around the margins of the pedicle valve and continue to grow outward, closely adhering to the surface of the host. When the size of the host is small, as in the case of a small crinoid column, the digitations in following the surface appear to clasp the host, but I can scarcely attach any morphologic significance to the fact.

ETHERIDGINA INCONDITA n.sp. (Pl. XIV, Figs. 16–18.)

Shell minute, seldom attaining a diameter greater than 2·5 mm., breadth somewhat greater than length; very irregular in outline. Pedicle valve cemented to foreign objects and conforming to their surface; area of attachment confined to the visceral region; beak free and slightly raised. Anterior and lateral margins of the valve deflected upwards at maturity and forming a trail. Brachial valve flat or somewhat convex, except along the anterior margins; here a rim is formed where the edges conform to the upturned margin of the pedicle valve. Hinge-line as long as or slightly shorter than the greatest breadth of the shell; a linear cardinal area, delthyrium, and well-developed teeth are present. Spines variable in number and confined to the margins of the pedicle valve.

This interesting little species is found in the Elmdale Formation (Pennsylvanian), in the vicinity of Beaumont and Cambridge, Kansas, attached to the larger brachiopods of the fauna. It occurs less abundantly in the Kansas City Formation (Pennsylvanian), in Jackson and Grundy Counties, Missouri.

Holotype: the original of Fig. 16, from Beaumont, Kansas (author's collection).

ETHERIDGINA ? SPONDYLIFORMIS White & St. John. (Pl. XIV, Fig. 15.)

1868. *Aulosteges spondyliformis* White & St. John, Trans. Chicago Acad., vol. i, pt. i, p. 118, text-fig. 2.

1915. *Strophalosia spondyliformis* ? Girty, Bulletin 544, U.S. Geol. Surv., p. 80, pl. x, fig. 8.

I know this interesting little species only from the description and figure given by the authors, and its relationship to the species here discussed is inferred wholly from a study of the description. Dr. Girty has figured and referred to this species a very obscure specimen from the Wewoka Formation (Pennsylvanian) of Oklahoma.

Hall & Clarke figure a *Strophalosia spondyliformis*; vol. viii, pt. i, pl. xvii*a*, figs. 25–6. This is a true *Strophalosia*; it is a rare species in the Kansas City formation. All specimens of the species in my collection show a misshapen and twisted pedicle beak, and, invariably, a cicatrix of attachment.

EXPLANATION OF PLATE XIV.

Fig.
1. *Etheridgina complectens* (Etheridge). × 4. View of pedicle valve, after Etheridge, 1876.
2. Id. × 4. View of pedicle valve, after Etheridge, 1878.
3. Id. × 4. View of conjoined valves, figure by Greger from Fifeshire specimen.
4. *Etheridgina radicans* (Winchell). × 2. Interiors of two pedicle valves, after Beecher.
5. Id. × 2. View of specimen with conjoined valves, after Beecher.
6. Id. × 2. View of pedicle valve, after Hall & Clarke.
7. Id. × 3. View of conjoined valves, after Hall & Clarke.
8. Id. × 3. View of pedicle valve, after Hall & Clarke.
9. *Etheridgina keokuk* (Beecher). × 2. View of conjoined valves, after Hall & Clarke.
10. Id. × 2. View of pedicle valve, after Beecher.
11. Id. × 2. View of specimen with conjoined valves, after Beecher.
12. *Etheridgina scintilla* (Beecher). × 4. View of pedicle valve, after Hall & Clarke.
13. Id. × 6. View of pedicle valve, after Hall & Clarke.
14. Id. × 3. View of specimen with conjoined valves, figure by Greger from specimen from type-locality, Louisiana, Pike County, Mo.
15. *Etheridgina ? spondyliformis* White & St. John. Copy of the original figure.
16. *Etheridgina incondita* sp. nov. × 4. Holotype. View of pedicle valve, specimen from Beaumont, Kansas.
17. Id. × 4. View of pedicle valve, specimen from Cambridge, Kansas.
18. Id. × 4. View of pedicle valve, specimen from Kansas City, Mo.

On a New Ammonite Genus (*Dayiceras*) from the Lias of Charmouth.

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

(PLATE XV.)

THE following account is based on the six specimens recorded by Dr. W. D. Lang in his paper on "The *Ibex*-zone at Charmouth, and its relation to the Zones near it"[5]. After mentioning the occurrence, in the top of the zone, of an apparently new Polymorphitid, Dr. Lang added the following footnote: "A striking form, 3 to 4 inches in diameter, with numerous, very thin costæ. Two specimens were found (not in place) in the winter, 1915–16, by Lieut. Dan Haggard, who presented them to the British Museum. The author found parts of three specimens in place in the Pyritic Marls in June, 1916. A sixth specimen, the best preserved of all, has been in the British Museum many years, and is labelled 'Said to be from Lyme Regis'."

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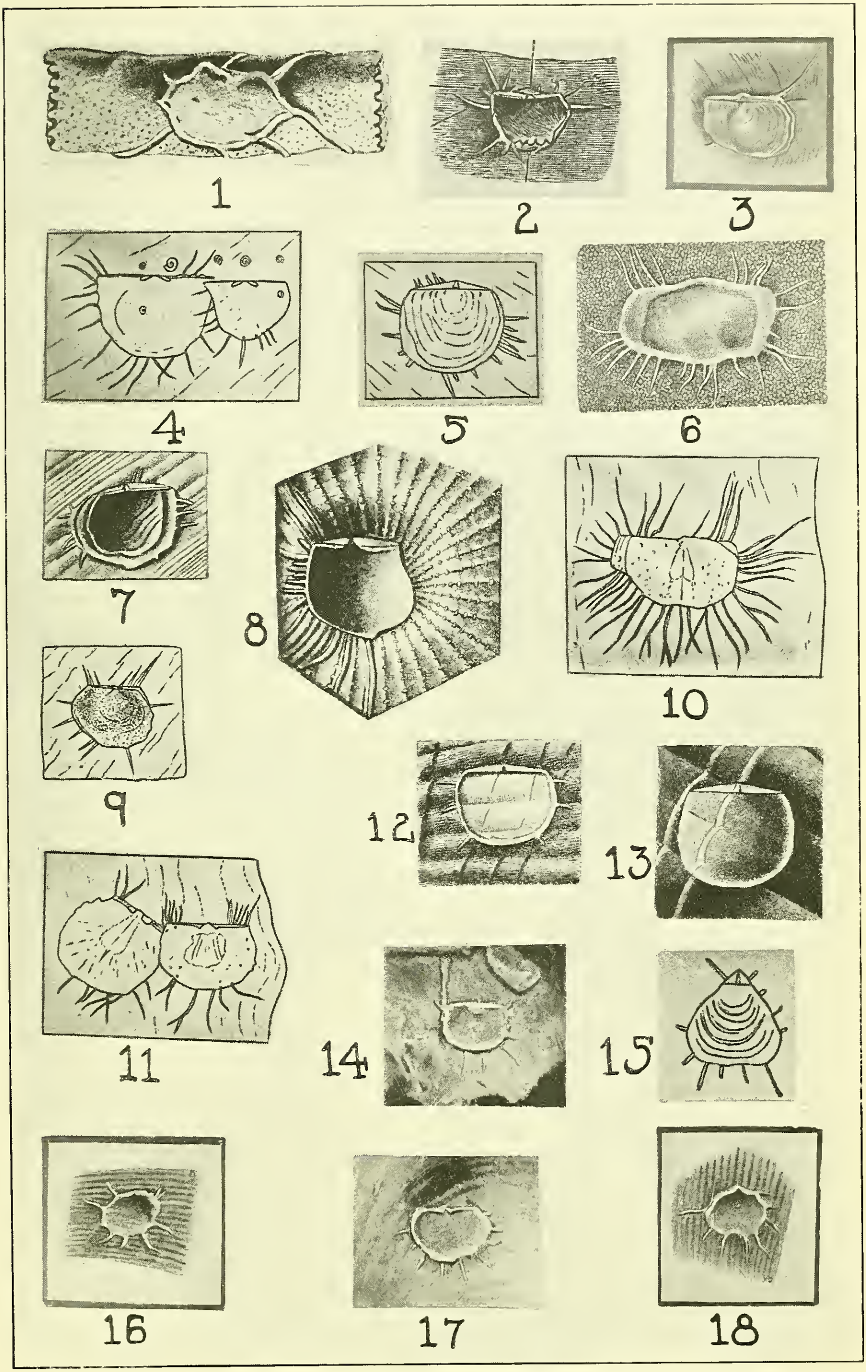
[1] F. R. C. Reed, "The Lower Palæoz. Trilobites of the Girvan district": Mon. Palæont. Soc., 1903–6, pp. 146–7.

[2] Also ibid., pl. xix, fig. 2.

[3] H. Woodward, Geol. Mag., 1880, pp. 97–9.

[4] L. Dollo, "La Paléontologie Ethnologique": Bull. Soc. belge de Géol. Mem., Bruxelles, Tome xxiii, 1909, pp. 406–17. See also H. H. Swinnerton, Geol. Mag., Vol. LVI, 1919, pp. 108–9.

[5] Proc. Geol. Assoc., vol. xxviii, pt. i, 1917, p. 32. A seventh example was found by Dr. Lang in May, 1920.



ETHERIDGINA.

The writer is indebted to Dr. Lang for permission to describe his specimens, also for many valuable suggestions. The writer also hopes to publish in the near future a complete account of the Polymorphidæ of the *ibex*-zone at Charmouth, especially of the successive developments of *Acanthopleuroceras* announced by Dr. Lang in his paper. These will offer a better opportunity for correlating the beds which yielded the new forms described in the present paper. Five of the six specimens mentioned above are considered to belong to one species, but their description is given separately, since, owing to differences in the mode of preservation, crushing, or rolling, each specimen shows interesting peculiarities which supplement the evidence of the holotype.

The specimen selected as type is the one that had been exhibited for years in the British Museum (Natural History) as an example of an "Ammonite replaced by Iron-Pyrites" (specimen No. Z 216). It bears the label "Apparently new. Bought at Lyme Regis, and stated to have been found there. F. H. Butler". The dimensions are:—

Diameter	83 mm.
Height of the last whorl	31 °/₀.
Thickness of the last whorl	21 °/₀.
Umbilicus	45 °/₀.

At a diameter of 60 mm. these percentages are respectively: 31, 21, 44. The specimen has the (limonitized) shell attached, except on the more prominent parts, such as the crests of the ribs and the peripheral tubercles. This abrasion is probably due to a certain amount of rolling, which would account not only for the rounding of the periphery but also for the apparent duplication of some of the costæ. Apart from this, however, there appears to be a flat septum in each costa, which itself was probably hollow and very sharp, if one may judge by the other specimens. The ribs may therefore appear flat and broad, after the style of annulate Dactyliocerati, even where there was abrasion of only the crest and tubercle, and where the inner shell or septum still adheres to the rib (Fig. 2). The number of costæ is 114 to the whorl at a diameter of 83 mm. and about 116 at a diameter of 55 mm. Each begins with a striking backward bend at the umbilical slope (Fig. 4), and describes a sigmoidal curve on the lateral area, ending near the ventral margin with an elongated tubercle or thick ending. In Fig. 3 this is indicated from the evidence of the other specimens; but in the holotype the periphery is more or less worn throughout.

The whorl-section is rounded, with its greatest thickness about midway between the periphery and the umbilical suture; but, owing to the wearing down of the ornament, the sides appear to be flattened on the last whorl; and, especially near the end, the shell is poorly preserved. From evidence, however, of the inner whorl, it appears that the sides were regularly convex, and this regular rounding is also shown in specimen C 18836. Fig. 1*b* is a restored outline-section.

The umbilical edge is somewhat abrupt and the slope is flattened where the costæ describe the peculiar bend shown in Fig. 4. The involution is very slight, which character, together with the peculiar costation, gives these forms a lytoceratid aspect. A specimen from the Crumbly Bed, shown to the writer by Dr. Lang, is in fact a (poorly preserved) *Fimbrilytoceras.*

Owing to the difficulty of removing the (limonitic) remains of the shell from the interstices between the ribs, the suture-line could not be exposed satisfactorily. Fig. 1*c* is composite, made up from portions of several suture-lines at a diameter of 65 mm., i.e. about a third of a whorl from the end of the shell. Since there are traces of the suture-line still at the end, the specimen complete with its body-chamber must have been over 120 mm. in diameter.

Specimen 3770 (Coll. W. D. Lang), from the Pyritic Marls, 16 inches below the Belemnite Stone at Westhay Water, $1\frac{1}{4}$ miles east of the mouth of the River Char, is nearly complete, though crushed, and at a diameter of 90 mm., has :—

Height of the last whorl	33 °/₀.
Umbilicus	44 °/₀.

The thickness of the shell is 22 per cent in the one place where there is no compression, so that there can be no doubt that the specimen is specifically identical with the type. The costation is just a trifle closer, however, since there are about 125 ribs on the last whorl. It may be added that, though the innermost whorls are not preserved, the peculiar costation of the species is already shown at a diameter of 15 mm.

Since traces of what probably was the last suture-line are shown at a diameter of 80 mm., the complete shell must have been considerably larger than the preserved portion. At this spot also (just before the commencement of the crushed body-chamber) parts of the shell are preserved on the periphery. The median row of tubercles was much more distinct on the shell than on the pyritic cast, and the rounded prominences composing it alternate in position with the thickened and forwardly-bent terminations of the lateral ribs. A very indistinct ridge in the shape of a Λ seems to connect the three lines of tubercles across the periphery.

Specimen 3769 (Coll. W. D. Lang), from 12 inches below the Belemnite Stone, Cliff Base, south-west of Golden Cap, consists of half a whorl of an Ammonite about 47 mm. in diameter. The specimen is partly crushed, but typical and extremely finely costate. It clearly shows the prominent median line of tubercles on the periphery, but the two lateral rows of tubercles are irregularly crushed against it in places. The specimen is not pyritized, as the others are, but preserved in the peculiar pyritic-marly matrix of its bed, and like other fragmentary fossils from this horizon suggests disturbed deposition.

Specimen 3768 (Coll. W. D. Lang), from the Crumbly Bed, exposed at low spring tides on the floor of Cann Harbour, Golden Cap, represents an impression, on a mass of pyrites, of a shell probably about 80 mm. in diameter. At a diameter of 47 mm. the height of the last whorl appears to be 30 per cent, and the umbilicus 44 per cent of the diameter. The typical close costation is shown already on the innermost whorls, and may be taken to characterize the specimen sufficiently, but the peripheral ornament is not preserved. At the diameter of 10 mm. the last half-whorl shows about thirty (?) costæ.

Specimen C 18836 (British Museum, Nat. Hist., Dan Haggard Coll.), from near Charmouth (500 yards east of the mouth of the Char River, not found in situ), is preserved in a pyritic concretion which obscures much of the shell and all the inner whorls. The specimen is uncrushed, however, except near the end, and measures about 60 mm. in diameter. Where the last whorl protrudes from the mass of pyrites, at a diameter of 45 mm., the thickness is 21 per cent of the diameter. The ornament is typical and the periphery is particularly instructive in this specimen; for it shows both the true character of the high, median tubercle, and the sharp points of the ends of the costæ; also the deceptive appearance of the periphery where the worn-down ornament produces a rounded ventral area with the flattened costæ almost touching the siphonal line. (Compare Figs. 2 and 3.)

The distinctive characters of the new form, as shown by these five specimens, then are: (1) an extremely fine and close costation and (2) a median row of tubercles along the siphonal line, accompanied by two lateral rows of elongated tubercles or rather the thickened terminations of the costæ. These five specimens are considered to belong to one species, *Dayiceras polymorphoides* nov. (genotype). the generic name being proposed (on a suggestion from Dr. Lang) to commemorate the important work of E. C. H. Day on the Lias at Charmouth.

The last specimen, No. C 18835 (British Museum, Nat. Hist., Dan Haggard Coll.), from about 500 yards east of the mouth of the Char River (not in situ), differs from the other five in having a less close costation, namely, 84 costæ on the last whorl shown, as compared with 116 in the type of *Dayiceras polymorphoides* at a similar size. It is preserved in pyrites, but crushed, and has portions of one of the high-zonal Acanthopleurocerates, characteristic of the Pyritic Marls, attached to it. Its diameter is 57 mm. The periphery unfortunately is very imperfect, and the trituberculation is indicated only near the end; whereas the first half of the outer whorl, owing to the crushing, shows a very thin venter with the ribs apparently meeting at a keel (after the manner of certain carinate *Polymorphites* or the extreme form of *Uptonia jamesoni* figured by Haug[1]). It

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[1] N. Jahrb. f. Min., etc., 1887, pl. v, fig. 1*b*.

should be mentioned, however, that here the periphery has also been worn down, probably to the extent of several millimetres. It is to be regretted that the state of preservation of this ammonite does not permit of more exact comparison with the other specimens described in this paper or with the genus *Polymorphites.* The suture-line seems to be considerably simpler than that of *Dayiceras polymorphoides*, though it could not be exposed clearly enough for delineation. On the other hand, the specimen shows the very peculiar costation of *D. polymorphoides* in places (if less close), also, apparently, the typical peripheral ornament. In the circumstances it seems advisable to consider it a distinct form from *D. polymorphoides*, and the name *Dayiceras langi* [1] is here proposed.

Since the development could not be studied in any of the specimens, it may be premature to speculate on the probable evolution of the new series and its connexion with the genus *Polymorphites* and the other Polymorphidæ. But in justification of the new generic name proposed here the following observations may be offered. The adult suture-line of *Dayiceras polymorphoides* is of the complex type of certain finely-ribbed (and probably post-*jamesoni*) *Uptonia*, the exact relationship of which both to typical *Uptonia* and to *Polymorphites* has yet to be worked out.[2] The typical group of the genus *Uptonia* has its maximum development in the upper portion of the *jamesoni*-zone, and the forms have a tendency towards continuing the costation across the periphery. Without going, for the present, into the complex interrelations of the family Polymorphidæ,[3] it may be mentioned that some forms, indefinitely referred to *U. bronni* (which, however, is keeled and has a comparatively simple suture-line), may show the lateral tubercles moved considerably nearer to the siphonal line, also an indistinct notching due to the median line of slightly raised apexes of the V's along the periphery. So far as the writer is aware, however, nothing like the fine and close costation of the new forms described here has been observed in these *Uptonia*. The genus *Polymorphites*, on the other hand, is characterized by a very simple suture-line. In the typical forms of this genus (the small-sized, very variable *Polymorphus* group, and not the forms of *Gemmellaroceras*, often included here) tuberculation of the periphery also occurs occasionally, notably in *P. caprarius* Quenstedt sp., though here the costæ are bituberculate. In the lineate species of the genus *Polymorphites*, however (with merely angular periphery), there is a certain resemblance to the new forms. But on present evidence it seems inadvisable to include the new series which, at Charmouth, occurs in post-*ibex* times (yet

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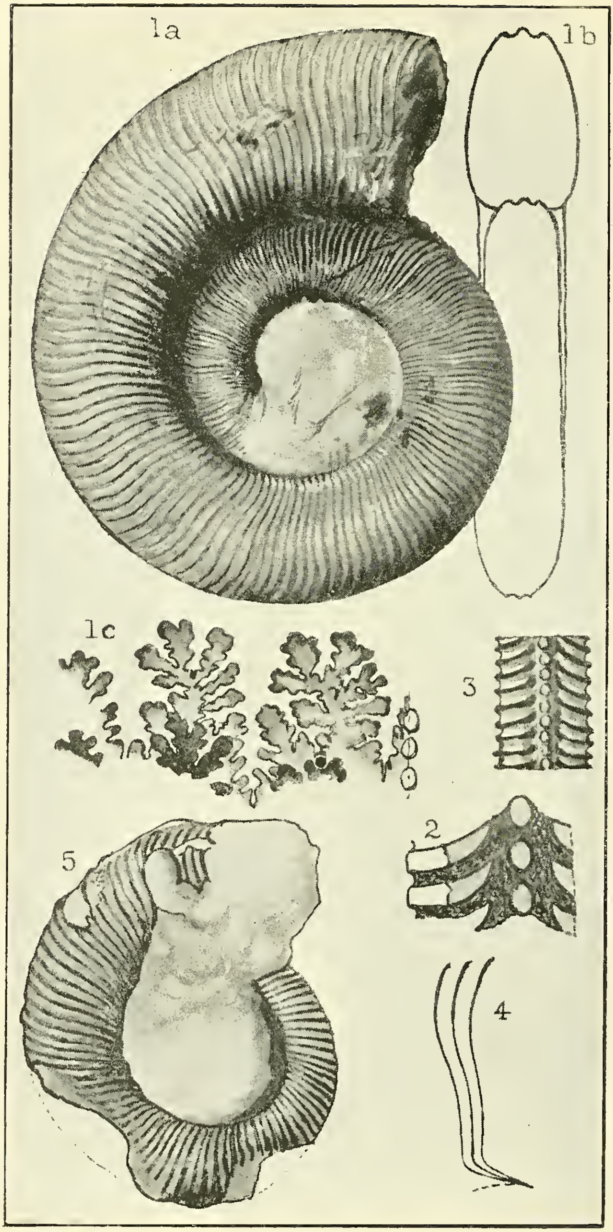
[1] Dedicated to Dr. W. D. Lang in recognition of his prolonged and painstaking investigations of the Liassic succession at Charmouth.

[2] The writer considers that *A. vernosæ* Zittel, probably a Toarcian form, does not belong to *Uptonia*.

[3] Confined, in the writer's opinion, to the *jamesoni* and *ibex* zones, and not including e.g. the Domerian *Bouleiceras* and later *Hildoceratids.*



L.F.S. del.]

New Ammonite genus (Dayiceras) from the Lias of Charmouth.

in the *ibex*-zone), together with *Liparoceras*, and which attained considerable size, in the genus *Polymorphites*. It appears to be a late and independent development of the Polymorphidæ, and possibly local, since nothing like the new forms has been recorded from such well-searched localities as e.g. Wurtemberg. It may be added that though the *ellipticum* group of *Tropidoceras*, with all its variations, and possibly some *Tragophylloceras* of the *Wechsleri* group, confused with *Amphiceras*, occur in Sicily, and both *Uptonia jamesoni* and *Acanthopleuroceras valdani* are widely distributed in the Mediterranean province also, there apparently is nothing comparable to the new genus *Dayiceras*, or, indeed, to the typical post-*jamesoni* genus *Polymorphites*.

EXPLANATION OF PLATE XV.

FIGS. 1–4.—*Dayiceras polymorphoides* nov. gen. et sp. Lias (Pliensbachian, *ibex*-zone), Charmouth. Specimen No. Z 216, British Museum, Natural History.

FIG. 1*a*.—Side-view of holotype, nearly natural size.

FIG. 1*b*.—Restored outline section.

FIG. 1*c*.—Portion of suture-line, magnified.

FIG. 2.—Portion of periphery, magnified, to show limonitic outer shell (dark), inner shell or septum, also limonitic (gray), and pyritic cast (two ribs on left, clear).

FIG. 3.—Periphery restored from evidence of several specimens.

FIG. 4.—Rib-curve, with strong forward bend at umbilical slope.

FIG. 5.—*Dayiceras langi* nov. Side-view, nearly natural size. Lias (Pliensbachian, *ibex*-zone), Charmouth. Specimen No. C 18835, Dan Haggard Coll., British Museum, Natural History. No sectional view is given, since the specimen is crushed.

The Mineral Composition of the Modern Fenland Silt, with special reference to Carbonate Minerals.

By F. HARDY, M.A. (School of Agriculture, Cambridge)

I. INTRODUCTORY

IN July of 1919 the writer assisted in a soil survey of the salt marshes of the north-west shores of the Wash.

During the course of the work it became necessary to examine microscopically specimens of marine silts forming the salt marshes, with a view to elucidating the reason why the silts generally have an abnormally high carbonate content.

It was found that the carbonate minerals in the material examined were of several kinds. Amongst them dolomite ($MgCO_3$. $CaCO_3$) was definitely identified. This discovery suggested a line of work both of geological and mineralogical interest, and also of possible agricultural value, for dolomite is a carbonate which is not affected appreciably by weak acids (such as those that are said to be liberated in soils by the decay of humus), and it seemed reasonable to suppose that the behaviour of the mineral in those soil processes involving the chemical action of a base, might be somewhat different from that of, say, calcium carbonate.

Hitherto chemical analyses of soils have included a determination of the total carbonate content (expressed as $CaCO_3$) irrespective of the mode of occurrence of carbonate The usual method employed for carbonate estimation in soil-analysis is that described by Amos.[1] In this method the soil carbonates are decomposed by acting on a known mass of the soil with fairly concentrated hydrochloric acid, which is slowly heated to boiling point. The carbon dioxide evolved is absorbed in caustic soda solution contained in a Reiset tower, and its amount estimated by double titration with standard acid, using first phenolphthalein and then methyl orange as indicator.

The value of the method lies in the fact that it gives accurate results with soils which are suspected of being on the border-line of deficiency of calcium carbonate, and hence it furnishes the soil-chemist with data upon which to instruct farmers as to the advisability or otherwise of liming arable land.

The prolonged boiling with hydrochloric acid involved in the estimation is sufficient to decompose any carbonate which is likely to be present in soils. It does not differentiate, however, between easily decomposed carbonates, such as the various forms of calcium carbonate (calcite, aragonite, etc.) and the more stable carbonates, such as magnesite, dolomite, and minerals allied to the latter, siderite, $FeCO_3$, ankerite, $CaCO_3 . (Mg, Fe)CO_3$; mesitite, $2MgCO_3 . FeCO_3$, breunnerite, $(Mg, Fe)CO_3$, etc.

The inquiry naturally led to two distinct lines of investigation, one of a geological and mineralogical nature, and the other of chemical and agricultural bearing.

In the present paper it is intended to deal with the geological aspect of the subject. The results of the purely chemical side of the work, with its attendant agricultural applications, are set out in another place.[2]

In order to account for certain peculiarities of the Fenland silt soils, it would perhaps be advisable first to summarize what is known of the origin and method of formation of the Fenland silts. The geology of the silt lands is described by S. B. J. Skertchley[3] in a Memoir of the Geological Survey, from which the following account is taken.

II. GEOLOGICAL HISTORY OF THE FENLAND.

The geological history of the Fenland commences with the breaching of the one-time continuous escarpment of Chalk, which

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[1] A. Amos, *Journ. Agric. Sci.*, vol. i, 1905, p. 322.

[2] F. Hardy, "A Preliminary Investigation into the Occurrence of different kinds of Carbonates in Soils," to be published in *Journ. Agric. Sci.*, vol. xi, part i, 1920.

[3] S. B. J. Skertchley, "The Geology of the Fenland" (Mem. Geol Surv.), 1877.

joined the Upper Cretaceous highlands of East Yorkshire with those of Norfolk. The agents which effected this operation were the rivers of the early Fenland, combined with the usual agents of subaerial weathering. The breach was probably completed in pre-Pleistocene times, but prior to the oncoming of the Glacial period the covering of Cretaceous strata was completely removed from the area, so that the underlying Jurassic clays were exposed. During the Ice Age a thick covering of glacial deposits was spread over the whole or greater part of the area. Subsequent depression of the land-surface allowed the sea to extend inland, so that a great bay resulted. It was in this bay that the true Fen-beds were deposited. The inflowing rivers caused an accumulation of alluvium near the shores of the bay. and the sea-currents brought down material from the coasts of East Yorkshire and North Lincolnshire. Gradually the bay became filled with sediments, and in the south and south-eastern regions swamp-plants began to grow. The remains of these subsequently gave rise to the peat lands of the Fens.

The silts of the north-western parts of the Fenland are chiefly of marine origin. They are still being deposited along the coast of the Wash, where they give rise to salt-marsh. As the tidal water is checked in its flow, the silt falls to the bottom, and thus a bank is gradually formed against the shore. As soon as this bank rises to a certain height (estimated at 8·6 feet above ordnance datum), *Salicornia* begins to grow on it. The stems of this plant assist in the further development of the marsh by checking the flow of the water, and thus allowing a longer time for the silt to settle, and also by holding up much of the fine material when the tide begins to ebb. As the marsh increases in height, other plants establish themselves, and "green marsh" results. Green marsh is only covered by sea-water at the higher tides. It marks the stage when embanking becomes practicable.

The material of which the Fen silt is composed has been derived, as already mentioned, from the soft strata (mainly glacial) of the Yorkshire and North Lincolnshire coasts, which are rapidly being eroded by the sea. The glacial deposits themselves are of the Purple and Hessle boulder-clay type. They have been derived from the rocks over which the ancient North Sea glacier passed in its movement from the Scandinavian highlands to the coast of England, and they therefore perhaps include material taken from the bed of the North Sea.

III. MINERALOGICAL EXAMINATION OF A TYPICAL SAMPLE OF MODERN FENLAND SILT.

The sample examined and described below was taken from the foreshore of the north-west coast of the Wash immediately to the seaward of the village of Friskney. It yielded the following results when analysed :—

(*A*) *Mechanical Analysis.*

Coarse sand (1·00 to 0·20 mm.)	0·05
Fine sand (0·20 to 0·04 mm.)	84·80
Coarse silt (0·04 to 0·01 mm.)	1·65
Fine silt (0·01 to 0·002 mm.)	0·95
Clay (below 0·002 mm.)	1·14
Loss on ignition	3·20
Moisture	0·50
	92·29

(*B*) *Chemical Analysis.*

Insoluble residue	84·750
Total carbonate (as $CaCO_3$)	8·980
Total phosphoric oxide (P_2O_5)	0·112
Total potash (K_2O)	1·224
Total nitrogen	0·034

1. EXAMINATION OF THE AIR-DRIED SILT WITHOUT PRELIMINARY TREATMENT.

A slide of the silt was prepared and examined under the petrographical microscope. The majority of the grains were found to be subangular quartz fragments. Their shape indicates that the grains had not been subjected to excessive rolling; they resemble typical boulder-clay quartz particles.

A few grains of felspar were also noted. Certain of these showed twin lamellæ and are probably of soda felspar.

The rest of the minerals (of density greater than 2·70) are described in the next section under the title of "heavy minerals". They constitute approximately 12 per cent of the bulk of the silt.

2. EXAMINATION OF THE SILT WITH A VIEW TO IDENTIFYING THE HEAVY MINERALS.

In order to obtain grains of convenient size for petrographical examination, a quantity of the silt was subjected to a 75 seconds sedimentation process in pure water from the 7·5 cm. mark of a beaker in the manner of a mechanical soil-analysis.

The sand fraction thus obtained was collected and dried. The heavy minerals were then separated by the use of a mixture of bromoform and benzine of density 2·70.

An examination of slides prepared from this heavy mineral portion of the sand fraction of the silt yielded the following results:—

The chief minerals identified were blue-green hornblende (arfvedsonite), magnetite, glauconite and chlorite, aragonite (in the form of shell fragments and broken oolitic grains), dolomite, ferriferous chert, augite, and tourmaline. In this list the minerals are arranged in their approximate order of abundance.

Besides the above there occur also in lesser amount rutile, muscovite, biotite, staurolite, epidote, zircon, kyanite, apatite, and garnet.

(1) Arfvedsonite is perhaps the commonest heavy mineral present in the silt. It has undoubtedly been derived from the igneous

rocks of Scandinavia, which are especially characterized by the presence of this blue-green strongly pleochroic soda-amphibole. (2) Magnetite occurs as numerous well-rounded opaque grains. (3) The glauconitic material present closely resembles that occurring in the Lower Greensand deposits of certain districts of East Anglia.[1] The glauconitic grains vary in colour from pale green to deep brown. Possibly much of the pale-green material is composed of chlorite, which is closely related to glauconite. (4) Aragonite occurs in the silt chiefly as abundant fragments of shells. Prisms of the mineral (possibly derived from shells such as *Inoceramus* and from Echinoids) also occur. In addition, oolitic grains are common. These show the characteristic zonary structure, and give dark crosses when viewed under two nicols. Many of the oolitic grains are highly ferriferous, and the aragonite of which they were originally composed may have been altered by impregnation with iron and magnesium into some such mineral as ankerite. (5) The dolomite present occurs as typical "fresh"-looking crystals of rather large size and with well-marked rhombohedral cleavages. Dr. Harker, who examined certain of the slides, expressed the opinion that the appearance of the dolomite grains suggests a secondary and comparatively recent origin of the mineral. Possibly the mineral was deposited from sea-water, and the crystals gradually built up during the successive wettings and dryings to which the modern Fenland salt-marsh silts are subjected. (6) The mottled grey-brown grains of chert owe their high density to the presence of abundant iron oxide in them. The grains are of comparatively large size, and possess a cryptocrystalline structure. (7) Augite occurs as colourless or pale-green angular fragments, which owe their shape to the imperfect cleavage of this mineral. (8) The presence of tourmaline is noteworthy. The commonest colour exhibited by the well-rounded drop-like grains of this mineral is olive-green, although a very few pink grains were seen. The tourmaline grains resemble on the whole those which characterize the Lower Greensand strata as described by Rastall. (9) Of the less common heavy minerals, rutile is conspicuous. It occurs chiefly as rounded brownish-red grains of typically high refractive index. (10) Muscovite is fairly abundant as thin flakes of various sizes. Its presence was rendered conspicuous by illuminating the slides under examination by light of grazing incidence. (A further comment on the occurrence of muscovite in the silt is to be found in the next section.) (11) Biotite is not very abundant, but it is undoubtedly present in appreciable amount. The mineral is of exceptional occurrence in sediments generally. (12) Staurolite occurs as rounded yellowish fragments of strong pleochroism and high refractive index. (13) Epidote was seen in a few angular fragments, of which a certain number possessed a thin coating of iron oxide. (14) Zircon is rare.

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[1] R. H. Rastall, "Mineral Composition of Lower Greensand Strata of East England": GEOL. MAG., Vol. LVI, 1919, p. 269.

When it occurs it resembles the grains of that mineral in the Lower Greensand. (15) Kyanite is present as large blade-like fragments, several of which exhibit the characteristic re-entrant angles, giving a waist-like appearance to the grains. (16) Apatite occurs in small amount as tiny rounded, colourless, highly refractive grains. (A further note on its significance in the silt is given below.) (17) Garnet is fairly abundant as colourless, more or less angular chips of high refractive index. Such grains of garnet are characteristic of many geologically recent sands of East Anglia,[1] and also of certain of the Lower Greensand strata.

3. Note on the Composition of the Finer Fractions of the Silt.

An attempt was made to identify the minerals present in the silt and clay fraction of the sample, but it was only found possible to recognize definitely the presence of quartz as the main constituent of the material; of muscovite in abundant small flakes; of tiny angular fragments of zircon, and of much calcareous matter.

IV. THE ORIGIN AND GEOLOGICAL RELATIONSHIPS OF THE MODERN FENLAND SILT.

Assuming that the sample of Fenland silt described above is fairly typical of the uniform deposit which is slowly being accumulated along the north-west border of the Wash, certain conclusions as to the relationship of the silt may be drawn from its mineralogical composition.

The general assemblage of minerals is very similar to that of certain of the geologically recent deposits of Cambridgeshire, as described by Rastall. It is almost identical with that of the finer parts of the plateau-gravels, which are most probably the residue of the boulder-clay of the North Sea glacier. Hence it may be assumed that such boulder-clay has furnished the bulk of the material of the modern Fenland silt.

The presence in the silt of calcareous oolitic grains, which have been generally somewhat altered by secondary processes, may be due to the admixture of detritus from weathered Jurassic rocks over which the Fenland rivers flow in their courses to the Wash. These conclusions are in full accord with the geological evidence which has already been summarized in Section II.

V. THE BEARING OF THE MINERALOGICAL COMPOSITION OF THE MODERN FENLAND SILT ON CERTAIN CHEMICAL CHARACTERISTICS OF THE SILT.

(A) Carbonate.

The establishment of the presence of two distinct kinds of carbonates in the silt sample examined is perhaps the chief point of chemical interest in the investigation. The writer has elaborated

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[1] R. H. Rastall, "The Mineral Composition of some Cambridgeshire Sands and Gravels": *Proc.* Camb. Phil. Soc., vol. xvii, 1912, p. 136, etc.

an analytical method for estimating the percentage amounts of the more easily decomposed ("calcitoid") carbonate, and of the carbonate of greater stability ("dolomitoid carbonate") in marine silt soils. Applying the method to the sample described above, it was found that of the total 8·98 per cent of carbonates in the silt, 5·75 per cent was easily decomposed by acids (i.e. soluble in N/3 acetic acid), whereas 3·23 per cent (by difference) required a stronger acid for its decomposition, and is assumed therefore to be of the nature of dolomite or allied mineral carbonate.

The details of the analytical method used in the estimation of calcitoid and dolomitoid carbonate in silt soils, and an account of the agricultural significance of the presence of these two kinds of carbonates in such soils, are given in the writer's forthcoming paper already quoted.

(B) POTASH.

The chief potassium-containing mineral in the silt is muscovite, and it is noteworthy that the greater amount of this mineral appears (from the petrographical examination) to occur in the finer fraction of the material. Although orthoclase felspar was identified as a constituent of the silt, it was noted that its amount was comparatively small. The only other possible potassium-containing minerals identified were tourmaline and glauconite. The former mineral, however, is so very stable that it is of no importance as a source of potash in soils containing it, and glauconite, which when fresh may contain as much as 8 per cent of K_2O,[1] is here present chiefly in a much decomposed state and also in such comparatively small amount that it may be left out of consideration as an important source of potash in the silt.

Thus the chief source of potash for the use of crops grown on Fenland silt similar to that described is muscovite.

According to the chemical analysis, the total percentage of K_2O in the silt examined in 1·224. This corresponds to about 10 per cent of muscovite (assuming the absence of other potash-minerals). It is relatively high as compared with the K_2O content of typical soils, which usually lies between 0·1 and 1·0 per cent. Nevertheless, the successful growth of crops (especially potatoes) in the cultivated regions of the reclaimed silt Fenlands frequently necessitates the liberal use of potassic fertilizers. This fact suggests that the potash supply of the Fenland silt soils is only relatively slowly available, so that it may fail to satisfy the full needs of certain crops which require an abundance of this plant food. It may be explained by the resistance to weathering which is a known characteristic of muscovite.

(C) PHOSPHATE.

The only phosphatic mineral found in the silt was apatite. Chemical analysis showed that the total phosphate (P_2O_5) present

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[1] Clarke, "Data of Geochemistry": *Bulletin* 616, U.S. Geol. Surv., 1916, p. 516.

in the silt sample is 0·112 per cent, which corresponds to about 0·28 per cent of apatite. Frequently in soils (especially in peat and other soils rich in humus), phosphorus probably also occurs as organic phosphorus compounds. In the case of the silt under consideration, the possibility of the presence of organic phosphorus is negligible, since the silt contains only 0·034 per cent of nitrogen (corresponding to about 0·48 per cent of humus). Hence we may safely assume that the only phosphorus compound present in the silt is the mineral apatite. The percentage of phosphate (0·112 per cent P_2O_5) is of average amount for a soil; the range for typical soils being between 0·06 and 0·20 per cent P_2O_5.

(D) OTHER MINERAL PLANT-FOODS.

The silt sample contained an abundance of magnesium-containing minerals, and also of minerals containing iron, sodium, and calcium, so that there is no danger of a deficiency of these essential elements of plant growth should the land subsequently be brought into cultivation.

The above results furnish an example of the importance of a mineralogical examination of a soil-type with a view to interpreting the figures obtained by a chemical analysis carried out along conventional lines. In the opinion of the writer too little attention is paid to the possible aid which mineralogy may afford the soil-chemist in his efforts to appreciate the special agricultural treatment frequently needed by certain soil-types under an intensive system of cultivation.

In conclusion, the writer wishes to express his indebtedness to R. H. Rastall, M.A., for his invaluable assistance and sympathy during the progress of the work outlined above. Also to E. J. Roberts, of the Cambridge School of Agriculture, for permission to use the results of the analysis of the sample chosen for examination.

SUMMARY.

1. A sample of modern Fenland silt containing 8·98 per cent of carbonate was found on mineralogical examination to include dolomite as well as aragonite in its mineral assemblage.

2. The dolomite is present in fresh angular crystal grains which suggest a secondary and recent origin of the mineral. It has possibly been deposited from sea-water which periodically covers the foreshore of the Fenland border of the Wash.

3. The general mineral composition of the silt resembles closely that of certain geologically recent deposits of Cambridgeshire, and points to the boulder-clay left by the North Sea glacier as the chief source of the material of which the silt is composed. The silt has mainly been deposited by sea-currents which carry southwards the eroded glacial deposits of the South Yorkshire and North Lincolnshire coasts.

4. An attempt is made to interpret the results of a chemical analysis of the silt in the light of its mineralogical composition, chiefly with regard to carbonate, potash, and phosphate. Muscovite, is found to be the main source of potash, and apatite of phosphate in the silt.

A Theory of the Marginal Drift.

By W. B. Wright

IT is a fact well known to geologists that the drifts laid down in the peripheral portions of the area affected by the Quaternary Glaciation differ markedly from those developed nearer in to the glacial centres. Beyond, perhaps, a vague suggestion that this may have been due to different climatic conditions during the successive stages of the retreat, no adequate or even partial explanation of the phenomenon has ever been brought forward. Pursuing a line of thought suggested by Dr. Matti Sauramo, in his paper on the glacial retreat in Southern Finland,[1] it now seems possible to offer an explanation based merely on the simple assumption of a greater degree of cold during the maximum of glaciation than obtained during the later stages of the retreat.

The peculiarities of the marginal drift which call for explanation may be briefly summarized as follows :—

(1) The absence along the outer edge of the drift-sheet of any terminal moraines, such as were developed during periods of halt or readvance in the later stages of the retreat.

(2) The attenuated character of the drift and the extreme indefiniteness of its margin, the so-called " feather-edge ".

(3) The almost complete absence of eskers and outwash fans, such as might indicate a normal amount of melting during the initial stages of retreat.

(4) The apparent absence of any of the phenomena of marginal drainage.

(5) The absence of drumlins or more generally of topographic expression of any kind.

(6) The presence of a covering of loess.

These characteristics are, of course, mainly of a negative character, but they are none the less remarkable. The first five might well be summed up in one word—feebleness.

The Fundamental Observation.—The conclusion of Dr. Sauramo, from which it is now proposed to build up an explanation of this feebleness of the outer drifts, is based on a study of the later phases of the retreat. These were in general characterized by active motion and rapid decay, the essential requirements for the production of end-moraines, eskers, and outwash fans, but a return at intervals

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[1] Matti Sauramo, " Geochronologische Studien über die Spätglaziale Zeit in Südfinnland" : Bulletin de la Commission Géologique de Finlande, No. 50, 1918.

to severer climatic conditions gives us some insight into the effects of reduction of temperature on the activities of the ice-sheet.

In virtue of its discharge into the waters of the late-glacial sea the outwash from the ice-margin, during its retreat across Finland, has produced in that country a series of clays with well marked seasonal laminæ, which give an effective measure of the rate of ablation. During the several halt-stages, the most marked of which are those corresponding to the inner and outer wreaths of the Salpausselkä Moraine, ablation as recorded by these laminæ was reduced to a minimum. It is a fairly safe deduction that these halts in the retreat were the result of a lowering of temperature, probably of mean annual temperature, but most certainly of summer temperature, since the coarse summer zone is almost wanting in the laminæ. Further, on mapping out the successive portions of the ice-margin and plotting the rate of retreat against the corresponding year, Dr. Sauramo discovered that, in almost every case, a halt was followed by an acceleration in the rate of retreat, lasting for a period of some fifteen years or so, after which there was a gradual reversion to the normal rate. From this result, combined with the fact that the laminated clays corresponding to these years of rapid retreat show no evidence of abnormally great ablation, he draws the conclusion that during the preceding halt-stage the margin of the ice-sheet had become thinner, and consequently wasted away more rapidly when the normal ablation was restored.

Now, wasting without any equivalent ablation is capable of one interpretation only. It clearly must be due to evaporation from the surface of the ice-sheet, that is, passage from the solid to the gaseous state either directly or with so little development of water that the latter merely moistens the surface snow and forms a zone of slush, but never gathers into runnels and streams. The zone of slush, according to the observations of Nansen, is not, even in the case of Greenland ice, which is undergoing ablation, of any great width. The conclusion, therefore, to be drawn from Dr. Sauramo's observation is that direct evaporation from the ice may, under sufficiently low temperature conditions, become an important factor in glacial control.

The Glacial Anticyclone.—It is now widely recognized that an ice-sheet, once it attains sufficient magnitude, establishes its own permanent meteorological conditions and wind system, the so-called "glacial anticyclone". It is nourished, not by snowfall as we know it, but by frost-snow or ice-crystals precipitated from the descending air of the anticyclone when it comes into proximity with and is chilled by the surface of the ice. The central portions of the anticyclone draw upon higher, colder, and drier regions of the atmosphere than the peripheral. The peripheral portions of the ice-sheet are therefore better nourished than the central, more especially if they adjoin an ocean. This is probably the explanation of the westward shifting of the centres of glaciation in the British Isles emphasized by Mr. Lamplugh, and the corresponding eastward shifting in North America. Mr. Lamplugh expressed the idea by saying:[1] "As the plateaus of ice rose higher in the path of the moisture-laden air-currents they must have gained increased effectiveness as condensers, thereby not only augmenting the snowfall in one quarter, but also diminishing the precipitation in the region to leeward." It might be more in conformity with modern ideas of the meteorology of ice-sheets to say that they drew down upon their surface the bulk of the moist air of the upper current which was passing across the ice margin towards the interior in virtue of the anticyclone circulation.

The Limiting Factors.—It is clear from what has been said above that, as an ice-sheet expands, its central area becomes starved, active precipitation being confined to the peripheral areas. Even in these latter, however, area for area there is less nourishment, as each sector of the front has a progressively narrower sector of the extra-glacial region to draw upon for its moisture. This is the first factor tending to set a limit to the growth of an ice-sheet, and it is to be noted that it is independent of any amelioration of climate.

The second and perhaps the more important factor is the increased wastage consequent on expansion. This is, of course, obvious if the ice-sheet is thrusting forward into the zone of ablation, but even if this zone is never reached there must ultimately come a limit. With increase in size and power there is drawn down the central pipe of the anticyclone a continually greater proportion of dry air from the upper regions of the atmosphere, and this spreading radially over the surface of the ice causes ever-increasing evaporation. Towards the periphery it no doubt partly mixes with, but also tends on account of its great weight to wedge in below, the moisture-bearing air descending in the zone of nourishment. The evaporation effect demonstrated by Sauramo to be a working factor in the colder stages of the Finnish retreat may thus become a really powerful agent of control during the rigour of the glacial maximum.

Effect of Accumulated Gradient and the Radial Snow-drift.—Thus, with failing nourishment and increasing wastage by evaporation, an ice-sheet may reach a limit of growth without ever extending into the zone of ablation. It is now losing by evaporation as much as it gains by precipitation. Its powers of expansion, however, do not stop here, for it has accumulated a gradient, and must consequently extend its frontiers until the gradient becomes so low as to be inoperative. In doing so it still further decreases its nourishment and increases its evaporation, so that the latter becomes dominant. It is already wasting from above downwards where it reaches its maximum extent, and this wasting continues until the front is again withdrawn to the line of balance, where precipitation and evaporation are equal. Here it awaits an amelioration of climate before ablation can set in and further withdrawal take place.

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[1] Pres. Address to Section C, British Association, York, 1906, p. 14.

The belt thus gently invaded with progressively weaker motion and as gently exposed without ablation by the slow downward wasting of the dead ice is the older and featureless marginal drift. The line of balance to which the ice retreated in the case of the European Ice-sheet is somewhere in the neighbourhood of the "Young End-moraine", perhaps a little to the south of it. The exact line was probably the northern limit of the loess, which, except in a few places, does not seem to reach right up to the moraine. It seems natural to suppose that the loess which covers the marginal drift was a product of the dry climate of the maximum of cold, and ceased as soon as there occurred a rise in temperature of sufficient magnitude to introduce the factors of ablation and more copious precipitation.

The principle of accumulated or residual gradient invoked to explain the advance beyond the line of balance requires further comment, because it is not clear that the ice-motion would not in the main have discharged the gradient concurrently with the establishment of the balance. Two considerations bearing upon this point are worthy of note. In the first place ice-motion must clearly be greatly slowed down as a result of extreme cold, for it depends entirely on the phenomenon of regelation, which becomes increasingly difficult with lowering of temperature. Though the exact references have escaped his memory, the writer believes that Shackleton and Scott have both commented on this checking of glacial movement by cold as being a fact within their experience. This conception, however, when closely examined, though it makes the probability of a residual gradient greater, does not settle the question. There is, however, another means of expansion, which probably becomes of great relative importance under conditions of extreme cold. This is the snow-drift on the surface of the ice-sheet caused by the radial winds. Peary considers that in the north of Greenland this is the controlling factor in distribution. Provided the ice-margin does not extend into the zone of ablation, it is clear that it may be considerably advanced by this method even after the establishment of the balance. What is not clear is that this mode of expansion acting alone would result in sufficient ice-motion at the sole of the sheet to produce even the feebly developed marginal drifts. A combination of both agencies of advance would meet the facts admirably, and account not only for the gradual attenuation of the drift at the feather-edge, but also for such "extra-glacial" phenomena as the "trail" of Southern England.

Absence of "Marginal Drift" in the neighbourhood of the Atlantic.—It is a noteworthy fact that the belts of marginal, featureless, and loess-covered drift in Europe and America do not extend to the shores of the Atlantic, but in these areas the strongly featured loess-free drift stretches south to the line of maximum glaciation. This result is deducible from the idea that the marginal drift is the product of an advance due to residual gradient and wind-drift after the establishment of a state of balance between precipitation and evaporation. In districts where there was a copious supply of moisture from the adjoining ocean, this balance was probably deferred to a very late stage or perhaps never reached at all. If the amelioration of climate which brought about the active motion and effective ablation of the later stages of the retreat supervened before this state of balance was reached, or even before the line of maximum extension was abandoned, then there could be no marginal featureless drift and no feather-edge in such a district. If there was ever any dead ice stage in these portions of the periphery, it did not outlast the maximum.

Summary.—Reviewing the argument once more so as to bring out its salient characters, we find that it may be briefly stated as follows. The investigation of Sauramo has established the efficiency of direct evaporation as an agent of glacial control during a cold spell. It is reasonable to suppose that during the much greater rigour of the maximum it was still more effective. Moreover, owing to the anticyclonic circulation the growth of the ice-sheets tended to reduce their nourishment and increase the depletion by evaporation. A balance may thus have been established between nourishment and depletion without the glacier front reaching the zone of ablation. When such a balance was established, however, motion continued owing to the already established gradient. In virtue of this residual motion, combined with the radial snow-drift, the ice-margin was advanced to its limit and subsequently withdrawn therefrom as a result of the still further increased evaporation, until it once more took up a position at the line of balance. This line in Europe is probably the northern limit of the loess, a short distance south of the " Young End-moraine ". Here the ice lingered until an amelioration of climate gradually introduced marginal ablation as a new factor. This change was accompanied by greater precipitation, an inevitable result of increased evaporation, due to the rise of temperature, in the extra-glacial region. The effects were slight at first, and the beginning of the withdrawal unmarked by any recognizable moraine. After a little, however, a new gradient was established, and the ablation becoming effective, moraine formation was initiated. The first of the moraines produced by this combination of active motion and rapid decay was that known as the Young End-moraine, and from this in to the centre a progressively greater development of moraines, eskers, and outwash gravels characterized the retreat.

REVIEWS.

An Introduction to Palæontology. By A. Morley Davies, D.Sc. pp. xi, 414. London: Murby & Co. 1920. 12*s.* 6*d.* net.

THE task of writing a small textbook on the palæontology of both animals and plants, suitable for students who have had no biological training, is one of great difficulty; but much may be expected when such a task is undertaken by an experienced teacher who, as shown by his work on the *Geography of the British Isles*, is also a lucid writer.

Instead of the more usual method of describing first the zoological characters of each group, the author begins with an account of the hard parts of some typical fossil forms, and then refers to the characteristics of the soft parts as seen in living representatives; but whether this, without illustrations, will give students a satisfactory idea of the zoological characters of the group seems doubtful. The order in which the various groups are taken is: Brachiopoda, Lamellibranchia, Gasteropoda, Cephalopoda, Trilobita and other Arthropoda, Vertebrata, Echinodermata, Graptolites, Corals, Porifera, Protozoa, Bryozoa (Polyzoa), Annelida, Plants. No reason is given for this order, and it would have been easier for the non-biological student to understand the relationship of the groups if a table of classification had been given at the beginning of the book. Similarly the use of the same kind of type for the names of groups of different value—Phyla, Classes, Orders, Genera, etc.—does not make for clearness. Very unequal treatment is accorded to different groups; thus 68 pages are devoted to the Class Cephalopoda, but the great Phylum Arthropoda (other than Trilobites) is disposed of in 4 pages; the Vertebrata receive 18 pages, and Plants 13 pages. The account of the Cephalopoda seems to be more detailed than is suitable for elementary students, and would have been easier to follow if it had been divided into three sections dealing with the Nautiloidea, the Ammonoidea, and the Dibranchiata respectively.

While some parts of the book have the style of a lecture, others, notwithstanding the author's prefatory remark, approach closely to the form of a descriptive catalogue. The author is certainly not sparing in the use of technical terms, and in some places gives the impression of trying to introduce as many as possible; this will certainly not prove an attraction to non-biological students. The two chapters on "Rules of Nomenclature" and "Divisions of Geological Time", although valuable for advanced students, seem out of place in an elementary work, and we think the space might have been put to better use by giving a more adequate account of some of the groups of fossils which are dealt with too briefly.

The original illustrations are satisfactory, but the figures copied from other authors have not in all cases been well chosen; for instance, in the echinoids the figures generally omit or show incorrectly the structure of the ambulacra—a feature of primary importance, and often not clearly seen in specimens.

We have considered this work from the point of view of the student of palæontology rather than from that of the specialist, and have drawn attention to some features in the hope that the author may have the opportunity of increasing the utility of his work. We regret that the author should have been contented with the statement "Valuable as a preliminary training in general Biology is to the student of Palæontology . . .", and we doubt if any petrologist would have made a similar remark implying that a preliminary training in Physics, Chemistry, and Mineralogy is not essential for the study of Petrology.

Pumpelly's Excavations at Anau, Turkestan, and the Origin of Domesticated Animals.

THE important archæological results of Professor Raphael Pumpelly's expedition to the Kurgans (continuously inhabited sites, now like Tumuli), of Anau in 1903–4 were made public by him in his "Interdependent Evolution of Oases and Civilizations", published in the *Bulletin* of the Geological Society of America (xvii, 1906, 637–70). The details are now made known in his "Explorations in Turkestan, Expedition of 1904, Prehistoric Civilizations of Anau" (Carnegie Institution), which contains Dr. Duerst's exhaustive report on the vertebrate remains. As to the archæology it will be enough here to roughly tabulate the results as :—

	Evidence.	*Date.*	*Proof.*
Anau V.		4th century A.D.	Sassanian coins.
Gap (strata denuded and lost).			
Anau IV.	4 feet.	Iron age (*c.* 1000–1300 B.C.)	Iron sickles. Wheel-made pottery.
Gap of 8 feet of strata apparently unoccupied.			
Anau III.	64 feet.	Copper age (*c.* 2000–)	29 copper objects ; flint knives, saws and scrapers, clay figures of Ishtar, bird-headed lion seal, wheel-made pottery.
Gap (strata denuded and lost).			
Anau II	15 feet.	Early copper age (*c.* 3500–)	Flint sickles ; 4 copper objects, sling stones, flint knives, hand-made pottery.
Anau I.	45 feet.	Stone age (Neolithic) (*c.* 5000–10000).	Domestic animals ; only wild animal bones at base.

The special interest to readers of the Geological Magazine will naturally lie in Dr. Duerst's report, and as this is elaborate one may best secure his general results by paraphrasing Professor Pumpelly's sketch in his "Reminiscences" (New York, 1918). There were 3,500 bones, of which one-third were skulls, jaws, and teeth. Excepting human skeletons, the lower 5 feet contained bones only of wild animals. The next 40 feet contain the record of the progress of domestication on this site *successively* of ox, pig, and sheep—and probably horse—as shown by the increasing porosity of the bones under the changed conditions of life, and by the diminutive size of the animals. First, out of *Bos namadicus* there was developed a large bovid with long horns (the same as found in ancient Egypt). At the end of Anau I there appeared a short-horned breed, which may have been produced from the long-horned ox or may be a new form brought in by the newcomers of Anau II. Domesticated pig begins to be found about 12 feet from the base. The wild *Ovis vignei* is in the lowest strata, but 28 feet above this animal had become domesticated, somewhat smaller in body, with smaller horns. This last persisted till the end of Anau I, but during the time a smaller variety was being evolved, until there was established a breed identical with *Ovis palustris*, the "turbary sheep" of neolithic Europe. The horse abounds in Anau I, and Duerst thinks it was domesticated; at any rate, it was descended from the wild *Equus przevalskii*, and appears to be the ancestor of the thin-limbed Arabian stock. Dog does not appear till late in Anau II (but its not being found is no proof of absence).

Of human remains two adults and seven young skulls were found. These are all dolichocephalic, not mongoloid, and seem to point to Mediterranean connexions.

That agriculture was known is shown by the siliceous skeletons of the chaff of a primitive variety of wheat and of two-rowed barley and chopped straw, all of which were obtained from fragments of pottery from the very lowest layers by Professor Schellenberg.

The importance of all these statements cannot be overestimated, but we can do no more here than refer the reader to the reports themselves for the details, and to Professor Myres's *Dawn of History* for their bearing on the early history of Man.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

Anniversary Meeting, *November* 9.—Sir William P. Beale, Bart., K.C., President, in the chair.

Dr. E. S. Simpson: "A Graphic Method for the Comparison of Minerals with Four Variable Components forming Two Isomorphous Pairs." In the spinel-chromite series the two pairs are MgO, FeO and Al_2O_3, Cr_2O_3, and the general formula is $(Mg, Fe)O . (Al, Cr)_2O_3$. The relative molecular preponderances of the components of each pair stated as a percentage of the maximum are given by the formulæ: $x = 100\ (m - f)/(m + f)$ and $y = 100\ (a - c)/(a + c)$, where m, f, a, c represent the number of molecules of MgO, FeO, Al_2O_3, Cr_2O_3 respectively. The values of x and y, calculated from a number of published analyses, and from new analyses of ceylonite from Camban, Western Australia, are plotted on rectangular co-ordinates. The four corners of the main square are occupied by the pure compounds $MgO . Al_2O_3$ (spinel), $FeO . Al_2O_3$ (hercynite), $FeO . Cr_2O_3$ (chromite), and $MgO . Cr_2O_3$ (here named picrochromite). Sub-species and varieties of intermediate composition are divided off in symmetrical areas within the square.

L. J. Spencer: "Fibrolite (= Sillimanite) as a Gem-stone, from Burma and Ceylon." Water-worn, prismatic crystals from the ruby mines in Upper Burma measure up to 1½ cm. in length, and are clear and transparent, with a pale sapphire-blue colour and marked pleochroism. A fine, faceted gem cut from this material is shown in the British Museum collection of minerals. Determinations were given of the optical constants; the birefringence shows a wide range, $\gamma - \alpha$ being seventeen times $\beta - \alpha$. On a somewhat similar, but etched, crystal from Ceylon the axial ratios were determined. Other crystals from Ceylon are pale greyish-green with a marked chatoyancy.

Dr. J. W. Evans: "The Origin of the Alkali Rocks." The alkali-igneous rocks form an exceptional series varying in composition from acid to basic, characterized by a high percentage of alkalies, especially soda, and a deficiency in alumina and the oxides of the divalent elements. They appear to occur mainly in areas where the earth's crust has, as the result of ancient folding or the accumulation of granitic rocks, consolidated to a considerable depth, and where the temperature gradient is abnormally low. Such are as are rarely subject to new folding, but are frequently faulted, and with these faults the alkali rocks appear to have a genetic relation. In such areas crystallization must proceed in the sub-crystal magmas, which are believed to be basic in composition under exceptional pressure, with the result that minerals with low specific volumes, having regard to the materials of which they are composed, will preferentially crystallize out. Garnet, zoisite, fibrolite, and kyanite are examples, the materials of which crystallize out under less pressure with greater specific volumes. As these minerals are mainly silicates of aluminium and the divalent elements, the uncrystallized residue will be poor in these constituents and rich in the alkalies, especially soda, which was present in the original magma in greater proportion than the potash. It will also contain the volatile fluxes in large amount. As a result of the faulting of the crust, this residue may be pressed out, find its way upwards, and give rise by further differentiation to the alkali rocks.

A. F. Hallimond: "Monticellite, from a Mixer Slag." The crystals, which are essentially monticellite containing about 20 per cent of olivine in solid solution, have the following physical characters: orthorhombic, a : b : c = 0·4382 : 1 : 0·5779; forms 010, 110, 021; refractive indices, 1·663, 1·674, 1·680; 2V 73¼°; specific gravity, 3·20.

Dr. H. H. Thomas and A. F. Hallimond: "A Refractometer for the Determination of Liquid Mixtures." A telescope and collimator with Websky signal are fixed in alignment; between them is inserted a parallel-sided trough containing the liquid to be determined, in which is immersed a right-angled prism of known index near that of the liquid. Two images of the signal are formed, and the angular distance between them is read on the eye-piece scale; this reading is proportional to the difference of index between the liquid and the prism. The scale division has the same value, whatever the index of the prism used.

EDINBURGH GEOLOGICAL SOCIETY.

October 20, 1920.—Mr. E. B. Bailey, M.C., B.A., F.G.S., F.R.S.E., President, in the Chair.

"Notes on the Structure, Character, and Relationship of the Lower Carboniferous Limestones of St. Monans, Fife." By David Tait and James Wright.

In this communication the authors gave a description, with diagrams, of the lower members of the Carboniferous Limestone Series which are exposed on the shore front in, and to the east, of St. Monans. Additional fossil lists from certain horizons were also given. Some of the points brought forward have not hitherto been published. Evidence was adduced to show that the "white" limestone of St. Monans undergoes a remarkable change from a coralliferous limestone at high-water mark at Coal Farm to a limestone of quite normal character at St. Monans Burn. Attention was also drawn to the difference in the cover of this limestone, and the change it undergoes towards low-water mark at Coal Farm. The "pseudo-brecciated" limestone of St. Monans probably owes much of its brecciated character to faulting. Besides the Coal Farm exposure, this bed also appears in its proper position on the west side of the syncline at St. Monans Burn. In all the positions examined, where it is undisturbed it may be described as a limestone of normal type; where it has been subjected to faulting, as at Coal Farm and at places on the western limb, it shows the "pseudo-brecciated" structure of the high-water exposure of the Coal Farm section. The overlying shales at such places are much disturbed and slickensided.

The higher limestones in the sequence retain their characters on both sides of the fold, but the intervening strata on the west are on the whole thicker than those on the east.

Description was also given of a remarkable limestone below the "white" limestone of Coal Farm. At high water this bed is normal and only 6 inches thick. Seawards it passes under a coralliferous layer, which gradually attains a thickness of 2 ft. 9 in., and from this point tapers away altogether. For a distance of 4 yards there is no limestone. It begins again as a thin coral bed of the same nature, thickens out to 18 inches, then dies away near low-water mark.

Attention was drawn to the nodular and other characters of these limestones and the evidence they afford of the peculiar conditions under which they were deposited.

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All Communications for the EDITOR should be addressed to
R. H. RASTALL, Esq., M.A., Christ's College, Cambridge.

All letters for Dr. H. WOODWARD, F.R.S., may be sent to
Tudor Cottage, Clay Hill, Bushey, Herts.

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